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**An investigation into the Murihiku toheroa
(*Paphies ventricosa*): mātauranga,
monitoring and management.**

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Abstract

The value of traditional ecological knowledge and associated traditional practices, or mātauranga and tikanga in the New Zealand Māori context, is playing an increasingly important role in the development of effective wildfoods management. Kaitiaki (environmental guardians) in Murihiku (Southland) are concerned about the successful transmission of the mātauranga surrounding the ecology, management and threats of the toheroa (*Paphies ventricosa*). Populations of toheroa, a highly prized endemic surf clam, are found at Oreti, Orepuki and Bluecliffs beaches within Murihiku of which numbers are historically low. Bluecliffs Beach has experienced large sand erosion leaving on 50% of the original habitat suitable for the toheroa. Twenty-five semi-directive interviews were conducted across a range of kaitiaki, local experts and scientists. Interviewees identified the main threats, concerns and gaps in the research surrounding the toheroa and dictated the main aims within this present investigation. Discussions surrounding the traditional practice of translocating toheroa revealed the presence of the third colony at Orepuki Beach, Te Waewae Bay. A population a third the size of the 2005 Bluecliffs Beach population has established at Orepuki Beach from translocation efforts by local community members. The maintenance of this population is of great importance to the resilience of the Te Waewae Bay toheroa given the degraded state of the Bluecliffs Beach population. The potential use of translocation as a stock enhancement tool may have broad potential to secure and increase the resilience of the Murihiku toheroa meta-populations. Translocation of adult toheroa to enhance existing stocks density and to establish new populations is considered the most practical option. The destructive nature of the current population survey techniques and its lack of adhering to tikanga lead to the wish for a non-destructive abundance index based on traditional search methods to be developed. The observation and counting of siphon activity (siphon tips and holes in the sand) provided a poor predictor of absolute toheroa density when compared with densities generated from the excavation surveys. However observing siphon activity in relatively warm temperatures (16°C and above) provides a 95% certain rate of detection during one search. Thus siphon activity searching provides a sound means to assess the presence/absence and distribution of toheroa colonies. The main threats to toheroa were identified as beach traffic, mass mortalities, illegal harvesting, predations, pollution and climate change. All of which are poorly quantified. Preliminary investigations provided evidence of beach traffic adversely

impacting juvenile (≤ 39 mm) toheroa, particularly those in the softer sand. Injury rates increased with vehicles with large, spaced lugs on the tyre tread and the motorbike test vehicle killed 18% of toheroa exposed to a single passage compared to an average of 3% for the car/utility vehicles. Similarly the Burt Munro Challenge beach race, an annual motorbike event held of Oreti Beach, caused a 72% (95% CI 40-90%) juvenile mortality rate within a 1-2 km stretch of the beach. Further research into quantifying the risk of beach traffic, along with important biological parameters (i.e age/size and maximum reproductive potential) need to be addressed. The results of this present investigation clearly illustrate how TEK and its associated practices are relevant to the effective management of wildfood resources. Future development into the management of the Murihiku toheroa should encompass an active adaptive management approach.

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List of abbreviations

°C	Degrees Celsius
BMC	Burt Munro Challenge
cm	centimetre
g	gram
GPS	Global Positioning System
ha	hectare
hr	hour
kg	kilogram
km	kilometre
m	metre
m ²	square metre
mm	millimetre
MAF	Ministry of Agriculture and Fisheries
MFish	Ministry of Fisheries
N ^o	number
NIWA	National Institute of Atmosphere and Water
QD	Toheroa density from excavation surveys
SC	Toheroa density from siphon activity counting surveys
TEK	Traditional Ecological Knowledge

Glossary

Aotearoa	New Zealand
hui	meeting
iwi	tribe
kai	food
kai moana	seafood
kaitiaki	environmental guardians
kaitiakitanga	environmental stewardship
karakia	prayer
kōhanga	nursery bed
kōrero	discussions
mahinga kai	food gathering places/species
mana	pride/prestige
manaakitanga	respect for others
Māoridom	the world of the Māori people, including their culture, society, and language
mārae	meeting house
mātauranga Māori	closest Māori translation of TEK
mokopuna	grandchildren
Murihiku	Southland
pākehā	Europeans
Papatuanuku	Earth Mother
pōha	bags of the lamina of bull kelp, <i>Durvillaea Antarctica</i>
Poua	Grandfather
rahui	area closure
rohe	area
rūnaka	Māori community council
Taitokerau	Northland
Tangoroa	God of the Sea
Tangata Whenua	People of the land
Tangata Tiaki	Māori customary fisheries appointees
taonga	treasured
Te Puka o Takitimu	Monkey Island
tikanga	customary rules and practices
tupuna	ancestors

wānanga	school/course
whānau	family
whakapapa	genealogy/lineage

CHAPTER ONE

Introduction

“The Māori language is a taonga [treasure] – to disregard the taonga of the language is to make it so that your traditions cannot be upheld – all of those traditions are forgotten”

Interviewee Q

1.1 Traditional knowledge, science and sustainability

Indigenous peoples have longstanding, close relationships with the environment. Through these relationships, indigenous peoples develop in-depth understanding about the ecosystems they rely on. Such knowledge is built on accumulated observations from which they use indicators to detect unusual occurrences within the ecosystems (Berkes in press). For example, detailed knowledge aids in the recognition of environmental change, inter-annual variations in stock abundance, changes in stock distribution patterns. Through monitoring indicators within the ecosystems, natural resource users also acquire knowledge to predict how the system will respond to unusual conditions (Neis *et al.* 1999; Johannes *et al.* 2000). The Denésq̄liné tribes of the Northwest Territories (Canada) traditionally monitor environment change through variations in body fat of Caribou (*Rangifer tarandus*), a primary prey species (Parlee *et al.* 2005). The tribes' close relationship with their environment provides them with the knowledge to measure shifts in the ecosystem's productivity and to construct well informed theories on the cause of these changes (Parlee *et al.* 2005). This in-depth and locally tuned knowledge is known as traditional ecological knowledge (TEK) and is the result of generations of observations and experimentation. Berkes (2008) defines TEK as “a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and the environment”.

Indigenous peoples utilise their extensive knowledge systems to develop regimes and practices, which are passed down over generations, to manage the natural resources on which they survive (Turner *et al.* 2000). Such institutions involve culturally

defined tools or rules to promote the protection and sustainable use of natural resources. These may include restrictions on harvest size, methods, areas, season and harvest specific life stages (Gadgil *et al.* 1993; Colding & Folke 2001). For example fishermen in the Maluku Province of eastern Indonesia follow seasonal harvesting rules for a range of marine resources, termed sasi. Those villages still practicing sasi have not experienced a fall in harvest yields of the gastropod *Trochus nilitocus* for several years compared to those villages that do not practice sasi (Evans *et al.* 1997). Artisanal and subsistence fishing communities also exercise enhancement strategies to ensure the persistence of marine stocks. Vanuatu fishing villages create 'clam gardens' where giant clams (Tridacnidae) are moved into protected areas, creating safeguards of the population. These clam gardens also ensure population maintenance as they facilitate increased recruitment through more successful fertilisation rates (Hickey 2006).

In the past, traditional knowledge systems have been overlooked and dismissed from natural resource management as they were believed to be static and inferior (Moller 1996; Newman & Moller 2005). Earlier debates have revolved around whether traditional management practices are relevant in current resource management (e.g. Alvard 1993), partly because they are not necessarily designed for conservation reasons alone (Smith & Wishnie 2000). While the sole purpose of some indigenous peoples' customs is to maximise harvest yields, the principles held within the knowledge of Denésq̄liné tribes or the traditional aquaculture practices of the Vanuatu fishermen could be successfully and effectively applied in the conservation and enhancement of natural resources. Hickey (2006) concluded that nothing will be gained from "re-packaging" traditional management systems in modern scientific approaches, i.e reinventing the wheel.

Fortunately, in recent years the value of TEK and its associated management systems have been realised (Johannes 2002). A more constructive approach has been developed, which focuses on the similarities between traditional and scientific systems, rather than prosecuting the differences. Sharing both traditional and scientific information and monitoring techniques is a particularly useful joining point to guide environmental management (Moller *et al.* 2004, Berkes in press). The principles and goals of both traditional and modern resource management have developed convergently, as both systems endeavour to manage the same ecological and social issues (Kitson & Moller 2008). Indigenous people have traditionally

attempted to balance maximum productivity with sustainable harvest rates to ensure the long-term viability of their resource – much like modern day resource management (Berkes 2008). Acknowledging the similarities in the underlying principles of modern and traditional management may allow for an increase in the understanding of ecological systems, the identification of gaps in the combined knowledge and the exploration of alternative approaches to management (Ellis 2005; Newman & Moller 2005; Shcakeroff & Campbell 2007). Combining the knowledge of indigenous peoples with the learnings of modern science offers an opportunity to conduct research and manage natural resources in a more holistic and culturally sensitive way (Aswani & Hamilton 2004; Drew 2005).

Both traditional and western systems have a lot to gain from each other if worked in respectful partnership (Moller *et al.* 2009 a,c; Berkes in press). However, incorporation of traditional knowledge and science is not simply a priority so as to maximise information – partnership is also needed to build social capital for environmental care and to be just. There is a large body of literature on environmental justice, co-management and environmentality that underscores the primary need to find participatory and just power sharing relationships. These are needed before the full power of bottom-up community-based conservation efforts can be effective and lasting. The involvement of indigenous and local people in initiating and developing management plans is crucial to successful collaborative management programmes (Borrini-Feyerabend 1996). Finding meaningful roles in local management and environmental decision-making is the key to changing the environmentality of local communities so that they are more likely to manage their local resources wisely (Agrawal 2005).

1.2 Mātauranga Māori and environmental management in Aotearoa

The consideration and inclusion of TEK and traditional management practices will help bridge the divide between traditional and modern management. In the context of Aotearoa (New Zealand), the active role of Māori, the indigenous people, in natural resource management has been hindered due to government land acquisition and the prohibition of traditional harvests (Moller & Lyver in press). Since the arrival of Pākehā (Europeans), the connection of iwi (tribe/s) to mahinga kai (food gathering places/species) has been restricted and their mātauranga Māori (closest Māori

translation of TEK) has faced erosion (Moller *et al.* 2009b). There is a strong belief that mātauranga Māori has the capacity to inform and guide natural resource management and conservation (Taiepa *et al.* 1997; Moller & Lyver in press). In Māori custom, it is an obligation to protect and be stewards of the environment. This is known as kaitiakitanga (environmental stewardship) and Māori have explicitly expressed their commitment to carry it out and to revive their cultural preferences and practices (Bishop 1998).

In recent years, mātauranga has been increasingly considered and included in more meaningful ways within management programmes (Moller *et al.* 2009 a,b,c; Moller & Lyver in press). Collaborative management including kaitiakitanga and modern conservation approaches offers a means by which the most sustainable management practices can be applied while still ensuring tangata whenua (people of the land) have a close association and link with their taonga (treasured) resources (Moller & Lyver in press). The inclusion of mātauranga in management programmes also ensures the empowerment of Māori and the preservation of their cultural identity (Tipa & Welch 2006). The equity and power sharing of conservation efforts between Māori and Pākehā is not only desirable but is a “fundamental constitutional requirement of the Treaty of Waitangi” (Taiepa *et al.* 1997).

1.3 Toheroa: present case study

The movement towards more Māori directed management of natural resources is growing in Aotearoa, particularly for those resources of significant cultural importance. Toheroa (*Paphies ventricosa* Gray 1894) a large, endemic surf clam are a highly appreciated taonga species for Māori. The largest toheroa populations are found in Taitokerau (Northland; Ninety Mile Beach, Ripiro/Dargaville Beach, and Muriwai Beach), with smaller populations on the Kapiti Coast (North of Wellington; Foxton, Waitarer and Hokio Beach), and in Murihiku (Southland; Bluecliffs Beach, Orepuki Beach and Oreti Beach). Historically toheroa were abundant throughout their range (Stace 1991). However, intensive exploitation from both commercial and amateur fisheries has led to substantial declines in both number and distribution (Cassie 1955; Stace 1991; McKinnon & Olsen 1994; Morrison & Parkinson 2001). The last commercial toheroa cannery closed in 1971 (Stace 1991), and both recreational and customary harvesting were increasingly restricted from the 1980s. Since 1996 toheroa have been managed under the Customary Fisheries Regulations, whereby

Tangata Tiaki (Māori customary fisheries appointees) authorise permits to harvest toheroa for culturally important events.

Belonging to the family Mesodesmatidae, toheroa are closely related to the tuatua (*P. subtirangulata*), deepwater tuatua (*P. donacina*) and pipi (*P. australis*). Toheroa live in the intertidal zone between mean-high and mean-low water levels of sandy exposed beaches. Adult toheroa spatially distribute themselves into distinct aggregated beds in the mid to low shore level, whereas juveniles are generally found higher on the shore (Cassie 1955). Toheroa are active deep-burrowers and can be found to depths of 10-20 cm where, during submergence, they extend siphons to the sand surface to filter feed and excrete waste (Redfearn 1974; Kondo & Stace 1995). Toheroa are the largest of the *Paphies* surf clams reaching size of 120-150 mm (Rapson 1952) and are believed to live for approximately 20 years (Cassie 1955).

Toheroa are broadcast spawners, with the peak spawning season occurring between November to February (Redfearn 1974). Toheroa have a free-swimming larval stage which lasts for approximately three weeks (Rapson 1952) and a sedentary, infaunal stage that occurs after metamorphosis. Settlement occurs along the high water mark. Juvenile toheroa experience rapid growth and are believed to reach approx 40 mm in their first year and consequently reach size maturity (i.e. 75 mm) in three years (Taitokerau toheroa; Redfearn 1974). Cassie (1955) reported the Murihiku toheroa have slower growth rates than those observed in the Taitokerau colonies. As the juvenile toheroa grow they migrate downshore to more preferable shore heights. Lower on the shore toheroa are saturated for longer periods and the water is more oxygenated, they can also withstand heavier wave actions by burrowing deeper (Kondo & Stace 1995). Toheroa colonies have been characterised by variable recruitment success and sporadic mass mortalities leading to large fluctuations in population abundance (Rapson 1952).

The Murihiku toheroa populations (Fig. 1.1) are of national conservation importance because of their outlying and limited distribution, long-term declines of both northern and southern populations, general degradation of marine ecosystem health and the importance of toheroa as a customary food of Māori. Ongoing conservation concern for toheroa in Murihiku stems mainly from severe decline in the population at Bluecliffs Beach (Te Waewae Bay) since the 1960s, (Beentjes *et al.* 2006; Beentjes & Gilbert 2006a). With robust monitoring techniques in place and the historical declines quantified, the kaitiaki (environmental guardians) now wish to identify the

main threats to the ongoing persistence of toheroa and consider options for intervention and restoration.

1.4 Research aims

The specific aims of this study were to:

1. Formally record the mātauranga Māori surrounding the Murihiku toheroa.
2. Identify and discuss areas of concern regarding the management and perceived threats to the Murihiku toheroa stocks.
3. Test and recommend community monitoring and enhancement methods.

The direction of the present study was dictated by the concerns expressed and the requested areas of study identified by the participating interviewees.

Chapter 2

Presents the mātauranga Māori surrounding toheroa obtained from interviews with kaitiaki, scientists and local experts. Topics discussed include toheroa ecology, trends in abundance and distribution, threats, details of traditional management, consensus on current management, the importance of education and transmission of knowledge and areas for future research regarding the Murihiku toheroa.

Chapter 3

Presents the results from a baseline population survey of the Orepuki Beach toheroa population and discusses translocation as an option for increasing the resilience of the Murihiku meta-population.

Chapter 4

Presents the results from a preliminary investigation into the reliability of using the traditional searching technique of observing toheroa siphon activity to predict toheroa abundance and presence/absence.

Chapter 5

Presents the results from a preliminary investigation of the putative impacts of beach traffic on toheroa and an assessment of the damage to the toheroa beds at of the Burt Munro Challenge beach race, an annual motorbike event held on Oreti Beach.

Chapter 6

Provides a discussion on how the mātauranga and the findings from the above three investigations can be brought together to guide the future management and enhancement of the Murihiku toheroa.

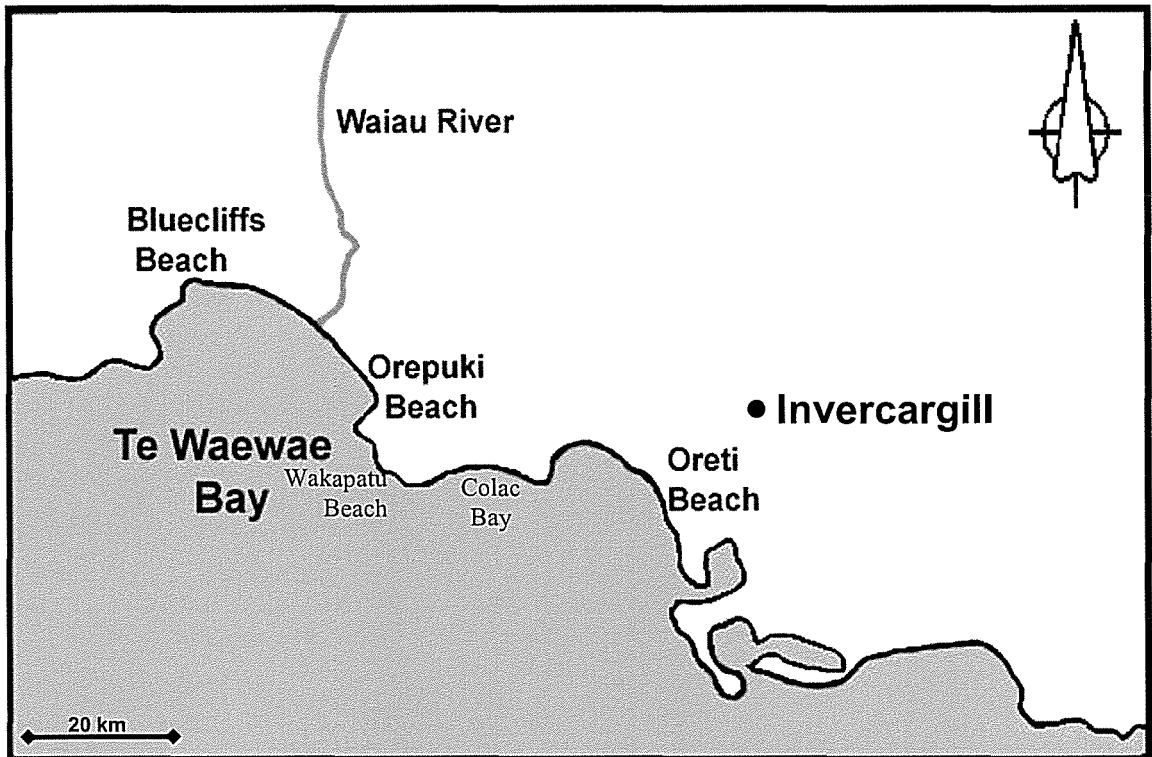


Figure 1.1. Locations of beaches which support toheroa populations in Murihiku (Southland), South Island, New Zealand. The main populations of toheroa occur at Oreti Beach, Orepuke Beach and Bluecliffs Beach. Anecdotal evidence suggested toheroa had been translocated to both Wakapatu Beach and Colac Bay in the past.

CHAPTER TWO

Interviews of the mātauranga surrounding toheroa (*Paphies ventricosa*) in Murihiku

“And that is the difference from way back when you used to get toheroa in the past, because it is hard work to dig them out, and back then your prize was beautiful and now you spend longer digging and the toheroa are smaller”

Interviewee J

2.1 Introduction

Traditional Ecology Knowledge (TEK) includes intimate knowledge of ecosystem functioning coupled with long term trends in the abundance and distribution of natural resources. It is this combination that can provide many useful insights into the management of wildfood species, including the identification of critical habitats and threats (Johannes *et al.* 2000; Moller & Lyver 2008). Knowledge and traditional management systems that encapsulate the protection and enhancement of natural stocks are of particular importance to conservation management (Drew 2005).

As the significance of TEK in natural resource management is becoming increasingly realised, the erosion of this knowledge is occurring at an equally fast rate. Many communities have moved away from a heavy reliance on natural resources, thus the knowledge is being lost through the lack of use (Turner *et al.* 2000). For many indigenous communities it is therefore only the elders that hold the specialist knowledge and as this generation ages the opportunities in which they can pass down their knowledge to the younger generations are becoming limited (Ulluwishew *et al.* 2008).

Furthermore, TEK has been eroded through the assimilation of indigenous peoples into western culture and the loss of connections with natural resources through harvest prohibitions (e.g for the kereru, New Zealand wood pidgeon; Lyver *et al.* 2008). Coupled with the effective capturing of TEK, institutions need to be developed to ensure its successful transmission. The rejuvenation of traditional knowledge systems will not only ensure the knowledge of the natural resources are

protected but also the values, customs and cultural identities of the indigenous/local peoples will be preserved (Stevenson 1996; Berkes 2008).

To ensure for the appropriate consultation and inclusion of TEK in management regimes, access to and the correct interpretation of TEK needs to be facilitated in a culturally appropriate way. Traditional knowledge systems are generally poorly documented, thus dialogues in which the traditional and science disciplines can communicate need to be developed (Johannes *et al.* 2000). Recording methodologies including interviews (e.g. Huntington 2000), workshops (Huntington *et al.* 2002) and map based exercises (e.g. McKenna *et al.* 2008) have been developed to assist in the capturing of TEK.

The kaitiaki in Murihiku fear that the mātauranga pertaining to the toheroa is rapidly eroding. Given the conservation concern of the toheroa stocks in Murihiku, recording this knowledge is even more important for developing the most effective management and restoration efforts. The involvement of the kaitiaki creates a relationship that will ensure the most effect collaboration between the local iwi and scientists. The purpose of this present study was to interview Murihiku kaitiaki with recent and past knowledge of toheroa populations, harvest management and threats to the toheroa populations. Interview discussions were also conducted to record traditional management practices including enhancement strategies of the toheroa within Murihiku and discuss the current concerns and future management options.

2.2 Methods

A total of 25 informants were interviewed across the Te Waewae Bay and Oreti communities. Given the heterogeneous nature of the knowledge held by local community members (Neis *et al.* 1999), key kaitiaki and local informants were non-randomly selected. Initial interviewees were a selection of tangata tiaki from the three coastal 'rūnaka' (Māori community council) of Murihiku (Oraka-Aparima, Waihopai and Awarua). Subsequent interviewees were identified through peer selection following Huntington's (2000) 'snowball sampling' methodology. A thorough interview series is accomplished once few or no new names are referred to (Huntington 2000).

Twenty kaitiaki, two local farmers from the Te Waewae Bay area and three ecologists were interviewed by *Te Tiaki Mahinga Kai*¹ researchers. Ethical consent for the interview series was obtained via the University of Otago Human Ethics Committee (Permit 07/099). Interviewees were also required to complete a consent form at which point participants could indicate whether or not they wished to be directly quoted. Each participant was assigned an alphabetic code to ensure anonymity throughout the written report.

Interviews were recorded with an iRiver dictaphone device from which the audios were transcribed. The average duration of the 25 interviews was 86 minutes. Interviewees were given an opportunity to edit their transcripts and ensure their original meaning was captured. Qualitative information from the interviews was analysed using NVivo™ software.

Interviews were semi directive in nature, allowing a conversational approach which can increase the likelihood of unanticipated topics coming up (Huntington 2000). Twelve of the interviews held knowledge primarily regarding the Bluecliffs' toheroa population and the others were from Oreti Beach or had knowledge of both sites. The interviews focused on the knowledge of toheroa ecology, trends in toheroa abundance and condition, the major identifiable threats and attitudes towards past and present harvest management.

2.3 Results and Discussion

2.3.1 Peoples' association with mahinga kai

Mahinga kai refers to the knowledge of harvesting areas and the harvesting, preparation and utilisation of traditional natural resources. Mahinga kai is not only a way for tangata whenua to live off the land but it is inherently important to their identity, mana (pride/prestige) and cultural well-being (Futter & Moller 2009). Interviewee R described mahinga kai as being "*just the way of life*".

The informants described the association between people and mahinga kai as going deeper than 'having a feed'. It is a more holistic connection, with firstly experiencing

¹ Te Tiaki Mahinga Kai (TMK) is a nation-wide collective of researchers, Māori environmental managers, and Māori community leaders from throughout Aotearoa who are collaborating together to support environmental management and kaitiaki of customary fishing areas.

and sharing the knowledge and then also understanding the system in order to utilise it in a sustainable and respectful way. Interviewee Q explained this by saying:

“But that’s what mahinga kai is about, you’re showing people how to utilise the resource that is there, available. If you didn’t know how to use it you wouldn’t be able to live there. And that’s what I’ve considered mahinga kai. It’s for the principles of actually passing on that knowledge to people that come into any particular area”.

Customary harvesting of taonga species facilitates and maintains relationships within and between whānau (family), and links them to their tupuna (ancestors) and to their rohe (area). Many of the interviewees discussed the importance of the responsibility of kaitiakitanga for sustaining natural resources for future generations.

Pākehā interviewees that sustained a connection with the coast also declared their ongoing respect and appreciation of the kai moana (seafood) resources. Those interviewees with tītī (muttonbird/sooty shearwater, *Puffinus griseus*) harvesting or farming backgrounds similarly expressed deep values of respect, appreciation and sustainable use of natural resources, as described by Interviewee C2:

“I think it is just the way we are and we endeavour what has worked to instil in the other generations and appreciation of everything around them be it wildlife, flowers, trees, whatever”.

The need to respect the resource was a recurring theme when the interviewees spoke about harvesting their kai moana. Interviewee B described this attitude as:

“We were gathers of mahinga kai along with our Pākehā neighbours. But I believe we always did it with a sense of preservation and not wishing to abuse the source, but it wasn’t a consciously taught thing. I don’t quite know how to quite explain it but we never went out to exploit it and we knew we shouldn’t, we just knew that and that must have been the result of the values we were raised with around mahinga kai”.

2.3.2 Toheroa as a taonga

Toheroa was classed as a delicacy and held in high regard by all of the 25 interviewees. Its large size and uniqueness of toheroa was thought to add to the attractiveness of the once readily available resource. Toheroa gathering was recalled

as being a significant part of whānau outings to the beach. The following passage from Interviewee U clearly illustrates that toheroa is strongly cherished amongst the local community:

“I think the toheroa beds are so few and so it was a real relish to have toheroa. It was such a special treat even, well for us it was because we didn’t live close to one [a beach with toheroa beds] and I know some of our cousins lived in the Rowallan area they went regularly and so they perhaps didn’t have the same feeling about it. Now they have because they’ve become so scarce. But to them it was quite a regular part of their kai moana gathering back then and for us it was the opposite. We just were very lucky to be able to have that experience of going getting them, preparing them and eating them. And I guess it’s like that for people who go to the Tītī Islands and they get tītī or any other relation to wait for that season and then have tītī. Well toheroa was like that for us”.

Interviewee W explained how toheroa has become such an iconic species:

“I don’t think it [toheroa] is ever going to be commercial species again..... in fact so little is taken it’s really a resource of historic significance. It is one of those special species, there is no doubt about it. It is up there with snapper, blue cod, pāua [abalone] and rock lobsters, one of those sort of iconic New Zealand species that even though no-one takes it any more, they know, or they remember, it’s just something in people’s memories about going to the beach and digging”.

Given the current state of the Murihiku stocks and the lifting of the harvest prohibition with the development of the Customary Fisheries Regulations, having toheroa on the menu is now a luxury. Interviewee R described this by stating:

“Yeah, and it’s more like an adventure now..... it’s a privilege because of the state of them, that I wouldn’t go in there just for willy-nilly because I want to have a feed. It’s sort of like for special occasions and yeah I wouldn’t waste an authorisation on just something to do”.

3.2.3 State of toheroa resource

TEK held by the users of a local resource is valuable for estimating and understanding historical and current changes in abundance, age structure and

distribution of the resource. Interviewees shared local knowledge on the locations of the densest beds and the declining trends in abundance they have observed over the years, particularly at Bluecliffs Beach. Many of the interviewees believed that while the toheroa are still abundant, the toheroa beds are nevertheless deteriorating. The awareness of such declines was reflected when interviewees compared catch rates from their youth to those of today:

“But you could go there in those days and if you wanted to you could’ve pulled out 100 in half an hour or less. They were everywhere. But they’ve dwindled, even in the seasons, when they had the seasons” (Interviewee L).

“When we were young and going there [Bluecliffs Beach] you could find them in lots of different places on the beach, whereas now it’s a real hunt” (Interviewee U).

Likewise the failure to successfully locate and harvest toheroa once issued a customary authorisation is an increasing occurrence in recent years. Some interviewees believe that many novice gatherers lack local and traditional knowledge about where to concentrate their harvesting effort or about the traditional methods to find the toheroa. This declining knowledge may be contributing to falling catch rates as much as the falling numbers of toheroa populations themselves.

Interviewees familiar with Bluecliffs Beach area reported that the toheroa colony appears to have a *“thinned out”* and has a much smaller distribution:

“They seemed to be fewer and further between” (Interviewee B);

“One time there was toheroa on that whole beach. You didn’t have to go and pick where you wanted to go, you just went down and got them. Now you will drive along or walk along it and you will find a few here and a few there, just little pockets of them” (Interviewee C1).

These perceptions are positively reflected in the truncated survey area at Bluecliffs from 11 km down to the current 5 km due to the reduction of toheroa bed boundaries. Several interviewees feared that the habitat degradation at Bluecliffs will continue, increasing the possibility of the toheroa becoming very scarce, or worse, locally extinct:

“The threat to the toheroa here is that flippin’ ground. And I myself believe they will eventually die on this [Bluecliffs] beach. Might be the odd patches where the gravel doesn’t come up, but they will never be like they used to be. And I think they will actually just slowly disappear” (Interviewee H).

Researchers too, fear that if the sand erosion continues, the toheroa population may be at risk of collapsing (Beentjes *et al.* 2006).

Significant declines in toheroa abundance since the 1960s are also indicated by scientific surveys conducted over this time period at Bluecliffs Beach and Oreti Beach (Beentjes *et al.* 2006; Beentjes & Gilbert 2006a,b). In the 1960s, the population of adult toheroa was estimated at over two million at each of these two beaches, while 2005 estimates were just 165 000 at Bluecliffs Beach (Beentjes & Gilbert 2006a) and 714 000 at Oreti Beach (Beentjes & Gilbert 2006b). The declines were steepest between the mid 1960s and mid 1970s, at Bluecliffs Beach, and in the mid 1980s at Oreti Beach, with ongoing declines at both sites since then (Beentjes & Gilbert 2006a,b). While the abundance of many shellfish populations in exposed, open beaches is typically highly variable, the declines documented by interviewees and researchers alike are indisputable.

The toheroa at Oreti Beach are considered by interviewees to be smaller than those at Bluecliffs Beach, with those at Orepuki Beach smaller still. A decline in both the size and condition of the toheroa flesh at Oreti Beach was noted by some interviewees:

“And that is the difference from way back when you used to get them, because it is hard work to dig them out, your prize was beautiful and now you spend longer digging and they are smaller.....all I know is that they are shorter and thinner by a long shot. The flesh inside is pathetic compared to what it used to be like, these beautiful great big - we used to call them the tongues - you know, just hanging on, and you had to really work hard and wriggle them to get them out. Well that doesn’t happen anymore because the tongues are so small” (Interviewee J).

2.3.4 Threats to Murihiku toheroa

2.3.4.1 Habitat degradation

Interviewees considered that the major threat to the Bluecliffs Beach population is the increasing degradation of the habitat available to the toheroa. The beach has

changed dramatically, with erosion and a loss of sand exposing rocks and gravel beds. At Bluecliffs Beach, the sand cover which is critical for toheroa existence has been reduced to 54% of its former extent, with the most rapid loss occurring during the 1980s (Beentjes *et al.* 2006). Once a wide, gentle sloping beach with fine sands, Bluecliffs Beach has transformed into steep gravel beds with only patches of intermittent sand. Interviewee W relayed how this affects the toheroa colony:

“At Bluecliffs Beach the sand is very shallow so the toheroa are really susceptible if they get a big movement or loss of sand and if they get exposed they struggle to get back in the sand. In places it really gets very shallow and under that it’s just gravel, so Bluecliffs is a very marginal habitat for them now, very marginal”.

In addition to the major physical changes to the beaches in Te Waewae Bay, interviewees reported that currents within the bay have altered, with much higher tides and large undertows now being experienced. The local people are devastated by the loss of their beautiful sandy beach and now perceive Bluecliffs as an unsafe place to swim. All but one interviewee who spoke about the habitat degradation attributed the beach erosion and loss of sand to the altered flow of the Waiau River, resulting from the hydro-electric power scheme in Lake Manapouri:

“It used to be a gorgeous beach, the whole beach from the Waiau Mouth right around to the Bluecliffs was a gorgeous beach, safe beach, and you could travel along at any time with cars and that. It was sand all the way.....It started to change, after they changed the Waiau [River] for progress then our beach, once they shut the Waiau off our beach changed completely to what it was. Well you can’t call it a beach now I hate going down there. It is not my beach now it is a foreigner to me” (Interviewee H);

“I don’t think the beach is right there anymore, because of the river. When they made the dam, that messed up the whole river” (Interviewee E2).

Hypotheses about the processes by which the reduced discharge of the Waiau River has influenced the flows and sediment budget of the Te Waewae Bay varied widely. However, the explanation offered by the interviewees above seems plausible, as the scheme has significantly reduced the flow by 75% and reduced the sediment load since water was diverted down into Deep Cove (Doubtful Sound) in 1969 (Keeley *et al.* 2002). The remaining interviewee, a local farmer of Papatotora, felt that the

increase in the presence of gravel on the beach was due to the decrease in stabilisation of the larger sediments upriver, which was in turn caused by the extensive deforestation that has occurred in the area.

2.4.3.2 Beach traffic

Vehicle traffic was identified as the major threat to the toheroa population at Oreti Beach, especially those driving along the high tide mark where the toheroa kōhanga (nursery bed) sites are situated:

“Well the other concern I’ve got is on Oreti Beach, it’s like Ninety Mile Beach, it’s a recognised road. So all the idiots from town race along the beach and they’re crushing those smaller toheroa” (Interviewee V);

“They drive along the beach there right on the nursery. Because it’s where the tide firms the sand but it’s fairly well up [the beach] and that’s right where they drive along. That’s where the spawn settles and that’s where they [the toheroa] start” (Interviewee A).

Interviewee F felt that the traffic is preventing the toheroa recruits from “*getting through*”, thus hindering population persistence and/or growth. The juvenile toheroa are believed to be the most susceptible to vehicle impacts such as crushing, dislodgement and suffocation as they are positioned much closer to the sand’s surface (Interviewee W).

Some of the kaitiaki believe that the threat of vehicles to toheroa recruitment is increasing:

“Since the early times when I was a kid there’s probably ten times more traffic now” (Interviewee F).

Oreti Beach is a particularly important recreational beach in Murihiku (Wilson 1999), and taking a vehicle onto the beach is seen as being important for both practical and enjoyment reasons. For example, Interviewee K said:

“Oh on a hot day you get a lot of people down at Oreti Beach that park, or swim and sit beside their cars. I think the car myself is an important part of the Oreti Beach experience. It provides shelter, you know if it’s a nice day there can be a bit of a breeze, or if it is a bit cool you sit beside the car on the lee side of the wind. It just makes it a wee bit more comfortable. And the

other thing is if you've got the car there you've got all your facilities there, and are not worried about somebody breaking into it. There's no real decent parking areas off the beaches anyway. Yeah all sorts of activities go on, people go out there and booze up, take their girlfriends out there, that sort of stuff".

The beach racing element of the Burt Munro Challenge² also came under the scrutiny of some of the interviewees who fear it might also be having some impact on the toheroa beds. The use of a grader to smooth the track prior to the race was witnessed to dislodge juvenile toheroa – as many as one every two feet along the 800 m track (Interviewee F). Furthermore the large number of bikes racing on the track and the spectators parking their cars on the beach were also concerns expressed by some interviewees.

Traffic intensity is significantly lower at both Orepuki and Bluecliffs beaches compared to Oreti. Some interviewees voiced their frustration that repeated attempts by the kaitiaki to have beach traffic managed have not been heard. One interviewee referred to the Ministry of Fisheries (MFish) people as "*having their ears on backwards*". Concerns expressed about vehicle impacts back in the 1990s were largely disregarded when the Southland Coastal Plan was formulated because of a lack of scientific evidence of the threat reported one informant. Chapter five of this thesis provides more detailed discussion on the possible threat of beach traffic to toheroa.

2.4.3.3 Predation

The major predators of toheroa identified in the interviews were both black-backed (*Larus dominicanus*) and red-billed gulls (*L. novaehollandiae*) and pied oystercatchers (*Haematopus ostralegus*). Brunton (1978) warned that predation of toheroa by sea birds should not be underestimated as a threat. Interviewee I1 also recalled toheroa siphons being found in the guts of flounders. Studies on predation of siphonate species by flatfish like flounder have found that 'siphon cropping' causes a decrease in burying depth of benthic bivalves thus increasing their risk of predation by probing predators (Zwarts 1986; de Goeij *et al.* 2001).

² An annual motorcycle event run in Murihiku by Environment Southland and the Southland Motorcycle Club

2.4.3.4 *Climate change and pollution*

Climate change was considered likely to have an adverse effect on the survival of the toheroa, particularly in altering the weather and tidal patterns. Pollution of surrounding waterways was repeatedly identified by the interviewees as a likely threat to the health of mahinga kai. Interviewee A explained the significance of polluted waterways:

“Because in Māoridom [the world of the Māori people, including their culture, society, and language] we talk about our Papatuanuku [Mother Earth] and the water is the blood flow, isn’t it? And if you dirty the blood flow then - stuffed! Hey, if you contaminate your blood....”

Interviewee A also felt that more effort needs to go into environmental care in general.

2.4.3.5 *Mass mortalities*

Many of the interviewees described witnessing mass mortality events of surf clams on the southern beaches. During these die-back events large numbers of toheroa were described to be washed up on the shore either dead or appearing too lethargic to burrow back into the sand (Interviewee K). From the kōrero (discussions) there appears to be two different set of events causing these mass die-offs. Many of the interviewees are of the opinion that toheroa are dislodged when stormy easterly weather prevails and that the shellfish are stranded by being washed up in ‘windrows’ at the top of the beach. This is in accord with the conditions that preceded the die-back event recorded at Bluecliffs in the 1970s (Eggleston & Hickman 1972). However, others have witnessed the die-back events during calm weather suggesting starvation, pollution, biotoxins, disease, high levels of freshwater and temperature-related factors were all possible causes. Interviewee P believes that an increase in the frequency of die-backs *“could be very detrimental”* to the toheroa populations.

2.3.5 Harvest pressure

Commercial harvesting of toheroa in Murihiku occurred in Te Waewae Bay for a brief period (Stace 1991). Over the last several decades toheroa have been recreationally exploited during open seasons of declining length with increasingly restrictive quotas. Bluecliffs Beach saw its last ‘Open Day’ in 1980 and Oreti saw its last in 1993 with an

estimated 20,000 people attending (Interviewee F). Looking back on the open days, interviewees were unanimously appalled by them, some describing them as *“the silliest thing that could ever be done”* (Interviewee V), *“a terrible experience”* (Interviewee J), *“total chaos”* (Interviewee O), *“an absolute disaster”* (Interviewee A), *“a sideshow”* (Interviewee Q) and *“a circus”* (Informant W). Although these harvesting events were managed by the (former) Ministry of Agriculture & Fisheries³, they were perceived as a great risk to the sustainability of the toheroa populations due to the sheer number of people that attended these events, overharvesting, damage to the beds from vehicles and disturbance of the sand. Interviewee D interpreted the threat as follows:

“I think years ago where they made their biggest mistake, is they put a season on the toheroa. Then everybody decided they had to go and get their share whether they wanted them or not. When there was no season there was no pressure, people knew if they wanted them they could go and get them, so nobody ever worried much about them, but the minute you put an open few days on it, oh everybody and their dog is there.....and they said you wouldn’t believe the number of toheroa in the Tuatapere dump, people would get them and didn’t know what to do with them, and then they would just fire them in the dump. Well what a waste of toheroa!”

There was a clear denunciation of the “Open Day” events given the large amount of wasted toheroa that resulted. One kaitiaki stressed his dislike for the open days as they were disrespectful of the kai (food) and the beach in general:

“Oh no, I’m not keen on it at all, I don’t think it’s a good way to manage the fishery. In Māori custom you only take what you need, and some things you also take enough to sustain you for the year, but with those events there’s so much waste. And in Māori custom you’re related to those things, in whakapapa [genealogy], so with all harvesting there’s karakia [prayer] because yes it was alright to harvest to feed oneself and one’s own, but not waste. You should absolutely not waste anything, and we know we’ve had reports of hundreds or thousands of toheroa ending up in the dump. That’s the reality of what happens, you know that’s a real crime in our culture for that to be happening” (Interviewee F).

³ The Ministry of Agriculture & Fisheries (MAF) formerly managed fisheries, agriculture and forestry. These institutions were split in 1995 so that fisheries are now managed separately by the Ministry of Fisheries (MFish). Several interviewees still referred the current government body as MAF where they clearly meant MFish.

After being allocated under the Customary Fisheries Regulations in 1996 a seemingly more preferable system was implemented which allows controlled, regular harvesting of toheroa. Beentjes & Gilbert (2006a,b) reported that the current customary take of toheroa off Oreti and Bluecliffs beaches were within the boundaries of sustainability in 2005. The Tangata Tiaki admitted to being stricter with authorisations for harvesting toheroa on Bluecliffs Beach given the population's declining status. The intensity of harvest pressure is recorded as a function of harvesters reporting their actual take back to the Tangata Tiaki, after being issued with an authorisation. The amount of toheroa harvested that is either not reported or is taken illegally cannot be measured. Harvesting without an authorisation, harvesting more than the allocated amount or using the authorisation of both the morning and evening tide, termed "double-dipping", are all forms of illegal take. Interviewees expressed concern that there could be as much illegally harvested toheroa coming off the beaches in Murihiku as there are authorised extractions.

Humans' natural sense of greed was alluded to several times as being the trigger for unsustainable harvesting activities occurring:

"The only reason they want them is that they are not supposed to have them. End of story." (Interviewee D);

"It's a bit like driving your car isn't it? It doesn't matter if they feel comfortable doing a hundred km/hr, they will still want to do a hundred and ten, aye. So if people go to get twenty-five toheroa, they just go, 'oh, I might just take twenty-eight' " (Interviewee T).

There are also fears within the communities that people are poaching toheroa for monetary gain (e.g. "raffling them off at the pub"). This is regarded as highly offensive and abusive of the resource (Interviewee Q).

Some interviewees acknowledged that they personally did not always seek an authorisation for their own harvests. This was mainly for philosophical reasons as these people believed they had a right to harvest and considered seeking an authorisation a restriction on this right. One Tangata Tiaki termed this type of illegal harvest as "customary harvest" and felt it was not a large threat as he knew they would be harvesting the resource in a respectful way. However, any form of poaching will go unrecorded in the Tangata Tiaki's records, leaving them with incomplete information for management purposes. Illegal harvesting is difficult to monitor,

particularly in isolated areas such as Bluecliffs Beach. Furthermore, monitoring efforts within Murihiku are stretched with only two fisheries compliance officers designated to monitor the coast for all types of fisheries. With the Tangata Tiaki's role only extending to the education of harvesters, some interviewees feel that perhaps it would be advisable if they also had more legal authority to prosecute those caught collecting without authorisation or exceeding the limits.

A significant number of the interviewees digressed into unprompted kōrero about increased access to mahinga kai areas is increasing harvest pressure. Furthermore mahinga kai gathering has changed with the development of deep freezers, with people taking more than required for one feed. As a general rule, the kaitiaki much preferred to eat fresh kai moana, especially when harvesting shellfish, but they considered overall harvest pressure on mahinga kai had gone up in recent decades because freezers allowed occasional harvesters to take bulk quantities. Many of the interviewees expressed their dislike of this, as explained by Interviewee V:

“And the story we were always taught, if you’re going to kill it, you eat it. If you’re not going to eat it, leave it alone, and it will be there tomorrow”.

With the development of more convenient ‘food gathering’ options such as supermarkets and deep freezers people are no longer reliant on going and catching/harvesting their kai in order to survive. Interviewee A felt that the transmission of mātauranga surrounding mahinga kai is suffering as a result of this:

“Well the whole thing has got pretty slack but also I think with the resources not being used as much, you’re not relying on those resources so much so you know the tikanga [customary rules and practices] is probably getting lost because it’s not so important, it’s not so necessary is it. Like I say you’ve got a freezer full of food there. You’ve always got something to eat. You’re not relying on somebody to put the net in and come home with fish for the village all that sort of thing you know”.

2.3.6 Traditional harvest management and tikanga

From the intimate knowledge generated with long association with mahinga kai, Māori traditional management systems developed tikanga to protect their natural resources. Together they have guided natural resource use for centuries in Aotearoa (Roberts *et al.* 1995; Kawharu 2002; Kitson & Moller 2008; Moller *et al.* in press b,c).

Some of the teachings referred to were meta-physical in nature, some referred to general values and beliefs of humans and their relationship to toheroa and mahinga kai. Other informants referred to 'resource use rules' that are clearly designed to protect the resource, and others to particular customs while harvesting the toheroa. Rather, implementation seems to be based on a complex set of 'rules of thumb' arrived at through accumulated historical experience. Compliance is often facilitated through religious belief, ritual, and social conventions (Gadgil et al 1993).

The primary purpose for adhering to tikanga is to harvest in a respectful and sustainable way, which reduces the damage and disturbance to the resources. Several of the interviewees described that the motivation to follow many of the tikanga was because if they did not treat the resources with respect they would no longer persist in the area:

"It's a cultural, traditional, spiritual type concept, but it's also recognising that kaitiaki responsibility of caring for the resource and not severely depleting it" (Interviewee F).

The most prominent tikanga described regarding toheroa was they were only to be harvested with your hands. The use of implements was thought unethical and damaging to the non-targeted toheroa (refer to Chapter 4). Interviewee C expressed this by saying:

"You endeavour to dig and take the right one, without having to damage everything else. It is a matter of conserving. Don't over disturb things".

Some kaitiaki were concerned that current scientific population surveys are damaging the toheroa. Their shells are thin and fragile, but perhaps more importantly, digging quadrats with spades violates the long-standing teaching to not use an implement of any nature for toheroa extraction. Furthermore, excavation styled abundance surveys are intrusive, expensive and labour intensive (Jordao & Oliveira 2003) and cannot therefore be performed by the kaitiaki themselves. Chapter four of this thesis investigates the efficacy of using the traditional index of the amount of toheroa siphon activity in an area to assess population size.

Similar strict rules included: 1) always return undersized shellfish; 2) take only enough for one meal; and 3) never waste what is taken:

“Well we don’t take anymore than we need wherever we go, what is the sense in having it lying around rotting, it’s silly. If everybody did that we wouldn’t be short of anything would we” (Interviewee I2);

“The thing about resources, it’s not about the shortage of it, it’s about the utilisation of it. The only thing that you should waste is actually the shells. So you shouldn’t use anything more than you can actually dispose of” (Interviewee Q).

Interviewees were also taught to avoid the toheroa kōhanga areas, particularly during the spawning season. Excluding these areas from disturbance reduces the chance of harvesting activities hindering recruitment. Some interviewees were taught to return their first catch. The purpose of this tikanga was described by Interviewee J as an *“acknowledgement of thanks”* to Tangaroa (God of the Sea) who supplied the gift of kai moana to them. Some acknowledged that this custom was probably of negligible direct effect in conserving the stocks, but had much wider and more fundamental value in reminding the people of their mutual relationship with the sea and its resources, and their responsibility to treat it wisely so that it would treat them well in return. Many of the interviewees recalled they were never allowed to shuck their shellfish below the high tide mark. Interviewee O simply explained this as *“people don’t live in cemeteries”* and therefore it was dictated that you should not expose the colony to the empty shells.

Several interviewees recalled their grandparents saying a karakia to ensure their safety while gathering toheroa to ensure their safety. Interviewees stated that the best time to harvest toheroa was on the full moon when the spring tides occurred and the toheroa were fat (Interviewee A, N). Interviewee A described the searching technique for toheroa as:

“...you walk backwards and you’d see where you were disturbing the toheroa and then you went back and okay there’s one there. And you just put your foot on it and waited for the next surge to come in and washed it out”.

By walking backwards he could correctly identify toheroa as they withdrew their siphons leaving characteristic impression in the sand. Upon identifying a toheroa, interviewees would get down on their knees and dig or continually agitate the sand into a liquefied state with their foot, ‘flushing’ the toheroa to the surface. Many interviewees also mentioned using the incoming waves to help wash out the toheroa.

While harvesting toheroa interviewees were taught to distribute their harvest effort across several big patches: e.g.

“We used to walk along the beach first and find patches where there was a big population and we would thin those populations out. We were taught if we only found one or two in a patch we were not to touch those, leave those, go for a bigger patch and thin that patch out” (Interviewee X).

Some kaitiaki believe that harvesting strengthens the toheroa populations, i.e. making them more productive as described by Interviewee A:

“Just by going there and not touching that breeding stock and only taking the surplus. So that you didn’t have so many sheep per acre. I’m quite convinced in my mind that you could bring a piece of beach back to that standard again”.

Traditional teachings also encompassed size restrictions to guarantee the breeding stock remained, ensuring optimal reproductive output. Some interviewees were taught to restrict the toheroa harvest to only medium-sized individuals, therefore leaving both the new recruits and the breeding stock alone. Interviewee Q and V both related this teaching to how a farmer keeps his livestock in their most productive state:

“Yeah, and you left the rest as breeding stock, to build up on it. And every so many years, Māori used to put a rahui [area closure] on it for a year so that stock sizes would be increasing into your breeding stock. And my understanding is that’s what the Māori were doing; they were practicing it, so it was a conservation policy in regards to a long term ecology and being able to use that resource. I just asked them [MFish] straight, you know I’m a farmer, and are you telling me that I should get rid of all my ewes and still have breeding stock for next year?” (Interviewee Q);

“A farmer doesn’t breed from the smallest stock he’s got, he breeds from the biggest and strongest. To me it’s only tikanga to do things like that” (Interviewee V).

Interviewee W introduced the term: BOFFFF Hypothesis, “*bigger, older, fatter, fecund, female fish produce more offspring*”. He explained the theory behind this as:

“We are finding more and more in fish populations it is important to have large fish and that is what so many populations are missing now. They have been fished down, it is not just that they have been fished down and that they are smaller but what you are missing from the equation is you haven’t got the big mothers that produce all the eggs, bigger eggs, more successful eggs and are more experienced they know where to go. It is all these sorts of things that really impact on how much recruitment you get. In other words - how much survival of the eggs that come back and turn in to recruits. In this case spat, so yeah you really want to have large fish there”.

The parallels between the mātauranga and science are clearly evident in this example. This is the source of much frustration for kaitiaki as this general principle has been appreciated for many generations in the Māori tikanga and is only now becoming clear to modern science after many fisheries are already greatly depleted.

The consequence of ‘fishing down’ the larger more fecund female fish has become more apparent to fisheries management in the past decade. Modern fisheries models are acknowledging the relationship between longevity and recruitment success and are being adapted to reverse the truncated age and size structures of many fish stocks worldwide (Longhurst 2002). By removing the ‘fishing down’ pressure on stocks will help ensure the persistence of the best spawners and increase the average fish size and genetic diversity within the effected populations (Berkeley *et al.* 2004a; Walsh *et al.* 2006).

For toheroa the minimum size limit of 100 mm was arbitrarily set by MFish, allowing two years of spawning (i.e. contributing to the breeding stock) after reaching sexual maturity of 75 mm that was estimated on Northland toheroa in the 1950’s (Rapson 1952). Toheroa management would greatly benefit from an investigation modelling the reproductive output across all size classes for each of the three colonies in order to dictate which harvesting regime would be the most sustainable. A maximum size limit may be more beneficial in ensuring the quality of the breeders and thus the resilience of the toheroa populations.

2.3.7 Traditional stock enhancement techniques

2.3.7.1 Translocation

The movement of toheroa to beaches with no previous known beds is regarded as a traditional stock enhancement tool (Interviewee F). Many of the interviewees are

aware of past attempts to translocate toheroa to new beaches within Murihiku including Orepuki, Wakapatu, Colac Bay (Fig. 1.1) and beyond (e.g. Moeraki, Otago). Translocating toheroa is recognised as a customary practice for the maintenance and enhancement of the stocks in Murihiku (Interviewee F). The philosophies behind past translocation efforts included both conservation concerns and the desire to spread the fishery across the area for more people to have access to it.

The main kaitiaki initiating translocations in living memory of the interviewees was Jack Te Au. Jack was a local farmer who devoted much of his time to toheroa surveillance and management at Bluecliffs Beach in particular, especially in the 1950s until the mid 1960s. He guided gatherers to the best spots on the beach where the toheroa were most abundant and largest and eventually became an Honorary Fisheries Officer with the Ministry of Agriculture & Fisheries. Jack and some other local kaitiaki were particularly instrumental in seeding a new population of toheroa on Orepuki Beach, at the eastern end of Te Waewae Bay. The existence of a third colony at Orepuki Beach was confirmed during the interview discussions. Jack's other efforts to establish new populations around Murihiku do not appear to have been successful, however see Futter & Moller 2009.

Given the current status of the Murihiku toheroa stocks there was a push from the kaitiaki to use translocation as a restoration tool. For example:

“It’s all about looking after them and it’s dangerous to only have one or two populations of anything. I’d hate to lose anything” (Interviewee F).

For successful translocations, aspects of toheroa ecology need to be thoroughly considered during the process of selecting translocation sites (Interviewee K; see Brumbaugh *et al.* 2006). Interviewees recommended that habitats for receiving translocated toheroa should ideally include features such as exposed beaches, fine sands, a large intertidal zone, ample food supply, freshwater seepage and minimal human disturbance. In order to ensure successful recruitment Interviewee W advised:

“You need to transfer enough individuals of both sexes or you may not get any fertilisation. You obviously need a critical mass, a critical biomass before you get some sort of recruitment that is going to sustain a population. The currents also need to be favourable for self seeding” (Interviewee W).

One kaitiaki felt that science would be particularly useful in this area to help investigate potential receiver beaches:

“I tend to think if they need to know whether an environment is right get somebody who knows and sort it out, because I don’t see any sense in shifting something to somewhere that is not going to suit them and they are not going to do any good, because you are not going to achieve anything. Plus you are going to lose the ones you shifted anyhow, so you have virtually gained nothing” (Interviewee D).

Interviewees recommended that toheroa be translocated to isolated sites and their location kept secret until the population has had a chance to establish before harvest pressures are introduced (Interviewee C & X). Mason’s Bay (Rakiura/Stewart Island), Sealers’ Bay (Whenua Hou) and the beaches west of Sandhill Point (towards Puysegur Point) were repeatedly mentioned as potential receiver sites. However, Interviewee H asserted that toheroa should only be shifted to beaches within their current range (i.e. between Oreti and Bluecliffs Beach) and that anywhere other than this would be unnatural. The philosophy behind this was that if toheroa were meant to live in a certain area, then a population would exist there already. It was also voiced that source populations should come from within the area (i.e. not shifting Oreti toheroa west of Te Waewae Bay). Interviewee D feared that bringing Oreti toheroa towards the west would be *“shifting them completely out of their environment”* and had a feeling they may not *“cope”* as well as those sourced from within Te Waewae Bay itself.

Tangata Tiaki advised that a precautionary approach would be most appropriate. Interviewee C expressed this by saying:

“I would hate us to take 50 out [and translocate them] and find that we had 50 dead”.

Toheroa which are about to spawn would be the best demographic to use in translocations. Both Interviewee F and R alluded to the use of pōha (bags of the lamina of bull kelp, *Durvillaea antarctica*) to transplant toheroa spat in. The original source of this kōrero has passed away and unfortunately the finer details of his methodology were not captured in this present study. Pōha may provide protection and nurture the toheroa spat in their new location in order to help them establish.

2.3.7.2 *Supplemental feeding*

Jack Te Au also experimented with active “*feeding*” of the Bluecliffs Beach population and the founding populations at translocation sites. Jack’s support of newly established and vulnerable populations is akin to the ‘soft release’ (Brown & Day 2002) strategies used by conservation biologists in recent decades for species recovery programmes. One interviewee knew Jack very well, spent a lot of time with him and shared his inspiration for supplement feeding the toheroa:

“He hit on a very great idea round at Whisky Creek here you know, it flows in there and the freshwater goes down in through the sand and it seems to be the place where you got good toheroa. So he decided that he would feed them and see if they would come any bigger, which they did, some were terrific size came out of there” (Interviewee E).

Jack’s supplement feeding efforts were known to promote the growth of the toheroa as Interviewee E reminisced:

“And all the people were saying “they [the toheroa] are big this year” and Jack was standing there and he had a bit of a grin on his face”.

The essence of his ‘feed’ was not uncovered during the interviewing process. The two interviewees closest to Jack gave conflicting reports on the ingredients, one thought porridge and the other swore it was not porridge but all “natural” products. Unfortunately the informant with the true knowledge of Jack’s mixture promised never to share the identity of his secret ingredients but she advised having the supplemental feed would be useful for toheroa restoration efforts. Jack’s methods of ‘feeding’ the toheroa involved making a furrow in the sand with a tractor and plough at low tide, parallel to the water. He would then spread the feed in the furrow which would be subsequently washed up through the toheroa beds with the incoming tide. Jack’s systematic experimentation with supplemental feeding to support the toheroa populations provides an example of techniques that have only evolved within conservation biology within the last two decades.

One kaitiaki was taught to actively bury kelp in the sand that had blown up on the beaches. He reported that there was a connection between buried kelp and toheroa:

“Where that kelp [got] buried you’d get an amalgamation of toheroa..... and they’d be good fish as well” (Interviewee A);

However Interviewee A also feared this teaching has been lost and due to less kelp appearing on the beaches, believes it is even more important to bury it now than ever. From Interviewee A's training in the use of kelp he believes there is a possibility that by burying kelp the health of a sandy shore could be restored. He hopes that a formal experiment is conducted to test the effectiveness of buried kelp on toheroa populations.

2.3.8 Current and future harvest management

The interviewees were generally happy with the current customary harvest management system (customary authorisations) in relation to sustainable management: e.g.

"I think it is good that it [toheroa management] is under kaitiaki-ship, definitely" (Interviewee J).

Interviewee D agreed that the current harvest management is helping to slow the decline of the toheroa. Similarly Interviewee T felt:

"It does feel successful we are gaining a wee bit of knowledge and understanding of how much toheroa is being accessed".

The current customary regulations and steady minimal harvesting was seen as far preferable to the earlier management by MAF using seasonal and annual prohibitions to moderate overall harvest. Several interviewees felt the authorisation process helps ensure the wastage of the resource was controlled: e.g.

"And I mean obviously these people that do come and get the permits must know what they're doing because they wouldn't be coming up there. But if you just say there's an Open Day, like how they used to announce it over the radio, people used to just flock out there in the thousands and didn't know what they were looking for" (Interviewee N);

"Because if you want to get toheroa and you have to go and get a permit, it means you want them" (Interviewee M).

However, there was some resentment amongst the older locals who felt that the authorisation system has restricted their access to their kai. Interviewee H expressed this by stating:

“I hate going to get a bloody permit! Because as I say I am 70 years old and I have been eating toheroa off that beach and all that and I don’t see why I should have to get a permit. I do get permits, because I got to, but I don’t see why I should have to get a permit. Because as far as I understand we are allowed our kai. It’s a violation of freedom [to have to get an authorisation], put it that way”.

Tangata Tiaki stated that authorisations to harvest toheroa would only be given for a significant, worthy occasion within their rohe:

“They would need to have a good reason, and we don’t give them a lot because it is just a taste” (Interviewee F).

Authorisations were often granted for elderly or ill members of the community, special family events, occasionally for civic occasions at Tuatapere but never simply for a party. The ethnicity of the applicant was not considered in the decision about whether to grant the authorisation or not. Indeed the kaitiaki expressed a strong value of manaakitanga (respect for others) and a duty to feed their people and visitors. The decision making process surrounding authorisation for one Rūnaka was described as:

“So we’ll consider each application individually and assess ‘well how do we think’ you know, do we think it’s appropriate that a customary authorisation is given out. Whether that be right or wrong we’ve set ourselves criteria just to give ourselves clear direction so that we have at least got some consistency in how we do deliver those authorisations aye” (Interviewee T).

Tangata Tiaki from Bluecliffs Beach said they attempt to reduce the number of the toheroa harvested in order to reduce the harvest pressure on the declining population which they believe is very vulnerable at present. Interviewee D described that they may turn down up to fifty percent of requests for harvesting toheroa from Bluecliffs, whereas Interviewee F suggested that the Waihopai Rūnaka are turning down approximately ten percent. Many of the Tangata Tiaki described they are strict on the number of fish authorised to be taken and often reduce what was originally requested by the applicant. Interviewee U explained the philosophy for cutting down the number of each species requested:

“We’re talking about our mahinga kai, we’re talking about the conservation and those things around it. So when we’re reducing it, it’s not because we think those people aren’t worthy of having a hundred toheroa, it’s because that’s what we think the beach can sustain”.

Interviewee T stated that:

“the customary permitting system would work better if the kaitiaki were given more authorisation to go and approach people and to go and talk to people [harvesters] and be recognised as such”.

Interviewee X also believed that Tangata Tiaki should have more legal authority over people who harvest illegally. However other kaitiaki stated firmly that compliance and enforcement is seen as fundamentally the role of MFish, even though the kaitiaki are the eyes and ears that can assist with surveillance to make the Fisheries’ jobs easier and more effective. Interviewee V felt that the fisheries officers within Murihiku need to be tripled in number because they are spread so thin over such a large coastal area and there are so many access points where poaching could occur without anybody noticing.

2.3.9 Continued customary practice, education and awareness

Interviewees pointed out that in general people use wildfoods considerably less than they have in the past. Phrases such as *“it’s another time, another place”* (Interviewee R) and *“the culture of Kiwis [New Zealanders] has changed”* (Interviewee M) were used to describe why such a drift away from mahinga kai has occurred. Several interviewees expressed their concern that people are losing their relationship with mahinga kai and are not being taught gathering skills and appropriate tikanga to protect the kai species. Interviewee Q stressed this by saying:

“I think the younger generation are actually getting further away from mahinga kai, not because they want to, it’s because it is not a necessity [now]”.

Several kaitiaki expressed concern that their people do not now know how to search for, open or prepare traditional kai such as toheroa. There is a need to ensure future generations can continue to harvest their traditional kai and gain the hands-on experience needed to maintain knowledge, identity, spirituality and sense of place

(Kitson & Moller 2008; Lyver & Moller in press; Moller & Lyver in press; Moller *et al.* in press b, c). It is from this experience that the connection with mahinga kai will be rekindled and the traditional sustainable management will be upheld. Educating and reconnecting the younger generations with mahinga kai were identified as priorities to help successful toheroa management:

“It’s all about ahi kaa⁴. It’s all about ...if you’re using the resource you’ve got to learn what the tikanga of that resource are and how to look after it. How they learnt to look after it over hundreds of years. It’s all about that you know” (Interviewee A).

In order to learn the tikanga and equally importantly, to understand why they exist and how they work, the community needs to be engaged with hands on experience/training. The main hindrance to the transmission of knowledge regarding toheroa management resulted from the fishery being closed for prolonged periods. Some interviewees were concerned that there is less opportunity for elders to teach the tikanga and pass down their knowledge. Some particularly knowledgeable members of the Murihiku community are becoming frail and have not had the opportunity to pass their teachings on (Interviewee A). Given that toheroa is no longer relied on as a staple food, the tikanga surrounding it is gradually being lost. The Tangata Tiaki themselves expressed distress that some of their people are not fully aware of the tikanga and the traditional ways of processing their kai. Interviewee F is concerned that the occasions where tikanga are not being followed will be detrimental to mahinga kai. Similarly Interviewee N emphasised that community members need to be taught how to correctly prepare their kai to ensure wastage does not occur.

Interviewee Q declared mātauranga as a taonga and stressed the importance of upholding it. Interviewee F shared an old saying that describes the value of learning the mātauranga:

“There’s an old saying - Te Manu e kai miro nana ke te ngahere, te manu te kai mātauranga nana ke te ao - and that’s saying the bird that eats the Miro berry his is the forest, the bird (or they’re talking about a person really) that

⁴ *Ahi kaa roa* literally means “keeping the home fires burning”- it is a term meaning continuing occupation and use of local resources.

devours knowledge, his/hers is the world. Like it's the old, old saying about the value of knowledge".

There is a growing realisation that in order to conserve the TEK and teachings there needs to be an active effort to get the tangata whenua down on the beach engaging in hands-on experience. One tangata tiaki stated that it is not a matter of telling your people how to do it but of showing them. If this connection is not rekindled soon, no-one will be knowledgeable of traditional ways of managing their taonga species. A managed transition to new Tangata Tiaki should be actively sought to ensure that the current knowledge is retained and applied to future management. Interviewee R addressed this issue by saying:

"But wouldn't it be nice to have someone who was coming up behind him so that you know in 20 years time there's someone actually there to take over, instead of throwing someone in the deep end".

Several interviewees discussed the importance of the mārāe as an institution to facilitate the transmission and involvement of community members as explained by Interviewee T:

"And I guess it's a gathering point, the sharing of information, sharing of minds and suchlike and so we've been able to feed off each other's knowledge, share that knowledge between each other".

One kaitiaki disclosed her inner conflict with writing down the knowledge taught to her by her Poua (Grandfather). Māori culture was traditionally oral, and further discussions highlighted the importance of experiencing places and learning the knowledge rather than reading it from a book:

"We walked the places and we talked the talk I think you do have to experience it to know because otherwise it's just a nice story and you know, you don't have the feeling and understanding behind it" (Interviewee Q).

However she also agreed that perhaps having the knowledge documented where people can read and learn about the wildfood resources maybe just the answer to initiate the rekindling of the relationships with mahinga kai:

"Maybe it's just the fact that we don't do it enough. We might go once a season or I do a wānanga [course] once every season and so maybe there's just too

many other things going on in their heads and they need the space to be able to actually go and experience that and remember and then not go back and face all those other outside issues. Or else it's just a wish that it's easier to have it down and know that it's always on your shelf and you can go and read. I don't know what it is" (Interviewee Q).

2.3.10 Partnership between mātauranga and science

Several interviewees asserted that scientific investigation involving aspects of toheroa ecology would be highly beneficial, supporting and strengthening the mātauranga. Interviewee T explained that given today's current ecological climate, science is needed to help understand increasing outside influences on natural resources:

"Things are not as they were anymore. There's all these other influences aye? All the contamination and stuff that's going on out there that wasn't there you know and so it's all influencing what's happening. It's all consequences of that, how will you know? It's only through Western science that we can find those things out now".

However the gap leading to the equality of modern science and mātauranga still needs to be bridged. Several kaitiaki felt their voice is not getting heard enough and have lost confidence that people will listen to them:

"Well they weren't listening before so why would they change? There is nothing different, they're not going to change. They seem to they think that mātauranga has got no place in the science world because there's nothing to back it up. And it's just years of observation which is all science is observations of the environment. It's just the same thing but there's no PhD's or whatever behind the names so it doesn't mean a great deal. There might be 700 years of knowledge but it doesn't mean a hell of a lot" (Interviewee V).

It is this indifference that needs to be resolved in order for the most effective management of taonga species such as toheroa.

2.4 Conclusions

Interviewing the local people and kaitiaki provided detailed information on past changes to the population size and abundance, and the most pressing threats to the

Murihiku toheroa populations. The knowledge of the locals in most instances corroborates the scientific studies that have been done over the past four decades at Oreti Beach and Bluecliffs Beach and demonstrates the accuracy and validity of the mātauranga in guiding management. Most of the customary users were well aware of the long term decline in toheroa abundance in Murihiku, that decline was most severe at Bluecliffs and that a new population at Orepuki exists. There are no historical records of a colony existing at Orepuki Beach and the informants collectively stated no population previously existed there, including the claims of several well practised toheroa gatherers. It can therefore be concluded with almost certainty that no toheroa colony was present prior to the reported toheroa translocating events. The primary motivation of the Kaitiaki translocating toheroa to Orepuki Beach was to spread the colony across to the eastern end of Te Waewae Bay. The kaitiaki and local experts also identified much of the same threats as noted by ecologists, especially the potential importance of vehicle impacts on recruitment and mass die-back events.

The traditional tikanga described above aim to protect habitats and minimise disturbance to the kōhanga, protect the breeding adults and minimise harvesting impacts. The kōrero clearly illustrated the ability of the traditional Māori systems to sustainably manage mahinga kai. Kaitiaki expressed their frustration of how the tikanga and mātauranga surrounding many kai moana species has been largely ignored. Apart from the displeasure of some kaitiaki who did not wish to apply for authorisations to gather toheroa, there was widespread support for the customary regulations in general. Careful and restricted allocation of gathering at Bluecliffs Beach was considered entirely appropriate for supporting a declining population.

The recollections of Jack Te Au and his devotion to toheroa provides an inspirational story for kaitiaki from which the ideals of his enhancement techniques can be developed to aide in the restoration of the Murihiku toheroa stocks. The investigation into suitable receiver sites, critical mass numbers and supplemental feeding to support the founding population alongside the mātauranga of the local observers presented in this present study can be pooled together to develop a successful restoration tool.

Several interviewees lamented the loss of knowledge and application of traditional tikanga around toheroa and mahinga kai management in general. The erosion of TEK and the understanding of traditional management practices need to be halted,

particularly for species of considerable conservation concern as the toheroa. Kaitiaki wish for an appreciation and respect to be instilled in the younger generations and the continuation of following tikanga to ensure the protection of mahinga kai. The goal of studies such as this is related to ensuring the traditional knowledge and tradition of local/indigenous people are upheld. Furthermore by combining the two knowledge systems a more complete understanding of the natural resource is compiled and the gaps in the knowledge easily identified. With the two forms of knowledge collaborated more effective management regimes can be developed.

From the korero of the 25 interviews several gaps in the knowledge surrounding toheroa have been identified to direct future investigations including: 1) population assessment of the newly discovered Orepuki population; 2) the calibration of the traditional abundance index, counting siphon holes in an area, to the actual toheroa abundance; 3) investigation into the putative impacts of beach traffic; 4) investigation into the causes and monitoring of die-backs events; 5) assessment of the illegal take; 6) investigation into a length versus reproduction output model for the three colonies to develop effective size limits for harvesting; 7) identification of potential receiver sites and development of reseeded strategies.

Partnership of mātauranga and science is one aspect of adaptive co-management to meet new ecological threats and maintain safe customary use in the new cultural and social context of modern lifestyles. A key safeguard is to have the kaitiaki in the driving seat for any such scientific research (Moller *et al.* 2009c, in press).

CHAPTER THREE

Orepuki Beach toheroa population survey

“We dug a trench down at low tide and just buried the toheroa in there in a long row and just let them go..... We just think we helped the population grow and establish”

Interviewee X

3.1 Introduction

Bluecliffs and Oreti beaches are the traditional toheroa harvesting sites within Murihiku. Managed as separate stocks, periodic population surveys have been conducted at both the beaches since the 1950s. The presence of a third local toheroa stock at Orepuki Beach was revealed during the interviewing process (refer to Chapter 2), and is situated on the coast between Te Puka o Takitimu (Monkey Island) and the Orepuki township, at the eastern end of Te Waewae Bay, Southland, New Zealand (see Fig. 1.1). The Orepuki Beach toheroa population is the result of several transplanting events carried out by local community members.

The translocation of toheroa to beaches with no previous known beds is regarded as a traditional stock enhancement tool (Interviewee F). The earliest transplanting efforts were by Jack Te Au, a local farmer who devoted much of his time to toheroa management and enhancement (refer to Chapter 2 for his background). No clear information was provided regarding how many toheroa Jack translocated from Bluecliffs Beach to Orepuki Beach or on how many occasions he did it. However, he was known to supplement feed his translocated stock at Orepuki Beach.

Interviewee D shared the following passage about his own personal transplanting efforts of toheroa to Orepuki Beach:

“Many years, about 50 years ago, there was no toheroa on the Monkey Island end of Te Waewae Bay. So an old chap Te Au was the honorary ranger way back at that time and we said to him, now we are going to be taking a few more than what we are supposed to be having, “Why?”, we are not going to be using any of the ones we are able to take, but we would like to take a few more, what we are going to do is take them down to what used to be known

as Kaitangata Point, which is back this way [west] a wee bit from Monkey Island, and we are going to plant them on the beach. So we did that a couple of times and never told anybody that we had put them there, and we just kept an eye on them and they were surviving. Then they must have started multiplying and unfortunately some of the locals found them, so yeah they got a bit of a hammering but to the best of my knowledge they are surviving quite well down there”.

Interviewee D disclosed that he moved approximately fifty adult toheroa to the middle of the Orepuki Beach, near Kaitangata Point (Fig. 3.1) repeatedly for three successive years. The latest recorded transplanting event was the efforts of an informant from the Bluecliffs area, he recalled:

“We did our ones [transplanted toheroa] about twenty years after Jack, and took about two or three hundred from Bluecliffs, around Whiskey Creek.....all in one go. We swung them in our backpacks on our motorbikes shot round the road to Monkey Island and threw them down where the freshwater stream comes down between Gemstone [Beach] and Monkey Island. We dug a trench down at low tide and just buried the toheroa in there in a long row and just let them go. So we are not sure if our planting survived or if Jack Te Au’s had survived and carried on. We just think we helped the population grow and establish” (Interviewee X).

Beentjes & Gilbert (2006a) acknowledged the existence of a toheroa population at Orepuki Beach. However, it has not yet been included in the regular population surveys conducted by NIWA (National Institute of Atmosphere and Water) for MFish. Moreover, MFish signs disclosing the terms and conditions of toheroa harvesting are in place at the Monkey Island beach access area indicating the knowledge of an established population. With no formal assessment of the Orepuki Beach toheroa beds, very little is known about the state of the population. The interviews (Chapter 2) suggest mixed opinions about the colony’s status. Some interviewees were dubious of its existence entirely, having not harvested toheroa at Orepuki themselves they were not giving in to rumours of successful transplantation. Some appeared doubtful of the population’s success, whereas others were certain it is a well established stock.

The origin of the Orepuki Beach toheroa population is of particular interest to the kaitiaki given the current degraded state of the Bluecliffs Beach population. Active management tools such as translocations maybe the only option to preserve the Te Waewae Bay toheroa. Interviewee D expressed this by saying:

“Now what has been concerning me for the last while is that their habitat around here [Bluecliffs Beach] is decreasing markedly. I’d say from what it originally was it will be down to less than a quarter of the habitat for them on the coast round here. My biggest concern was if we don’t try and shift them somewhere else and get them established we are going to lose them”.

The Orepuki Beach toheroa beds were almost certainly established by translocations in the 1950s (Chapter 2). This population therefore provides a unique opportunity to investigate the success of transplanting efforts of toheroa to a novel beach (i.e. a beach outside the toheroa historic range). The translocation of toheroa also has the prospective use for enhancing the density of existing toheroa stocks (Akroyd 2002). If proven successful, transplanting toheroa has the potential to provide a restoration tool for enhancing existing stocks to more closely resemble historic levels and help to ensure more populations are established within Murihiku.

In addition to assessing translocation as a viable restoration tool for toheroa, monitoring the state of the Orepuki Beach toheroa population is more crucial due to the degraded habitat and declining numbers at Bluecliffs Beach. The success of the historic transplanting efforts has two major implications for the management of the Te Waewae Bay toheroa stocks. Firstly, assessing the population status of the Orepuki Beach population will illustrate whether a significant safeguard population has been established within Te Waewae Bay, should the Bluecliffs Beach population collapse. Secondly, the kaitiaki need to have knowledge about the population size and stock structure of the Orepuki Beach toheroa colony in order to manage it sustainably. Ensuring overharvesting does not occur at the ‘newly’ established site is imperative if Orepuki Beach is to support Bluecliffs Beach’s harvesting pressure in the future.

The primary objective of this chapter was to determine the abundance, distribution and size structure of the toheroa population at Orepuki Beach. From this, survey comparisons with the most recent data accessible from Bluecliffs (the source population) and Oreti Beach toheroa populations were made to assess how

successfully the translocated toheroa have established. Relevant discussions about the use of transplanting for restoration and enhancement purposes are also addressed.

3.2 Methods

3.2.1 Site Description

Orepuki Beach is located at the far eastern end of Te Waewae Bay, running east from the Orepuki township (Fig 1.1). Orepuki Beach is classified as a dissipative beach, following McLachlan's (1990) definition of having "fine sand, heavy wave action and often also larger tide ranges; they have flat slopes and wide surf zones in which most wave energy is dissipated". Although mostly homogeneous, at the western extent of Orepuki Beach the intertidal zone is more dynamic with a steeper gradient and coarser, darker sands. Orepuki Beach is bordered by high cliffs with small, marram grass (*Ammophila arenaria*) covered sand dunes occurring at the cliff base for a 500 m section in the middle of the survey area (north of Kaitangata Point; Fig. 3.1). Freshwater streams flow down the intertidal zone at either end of the survey area (Fig. 3.1).

3.2.2 Survey Design

The toheroa population at Orepuki Beach was surveyed using a stratified random design. The survey methods were based on those developed for the periodic surveys at Bluecliffs and Oreti beaches (see Beentjes & Gilbert 2006a,b) to allow comparisons of the results. The boundaries of the survey area were defined by assessing the presence/absence of toheroa using the traditional method of searching for the siphon holes which results from toheroa retracting their siphons when disturbed (Metzger 2007; refer to Chapter 4). Akroyd (2002) and Morrison & Parkinson (2008) used this technique on Taitokerau toheroa colonies to identify the boundaries and zones of varying densities within the beds. The presence of toheroa beyond the northern boundary of Orepuki Beach survey area was repeatedly checked during the survey period to ensure the full extent of the bed was included in the survey. No siphon holes were found between the northern boundary of stratum 16 and the neighbouring Gemstone Beach (Fig. 3.1). The survey area (1.6 km) was divided into sixteen 100 m wide strata (Fig. 3.1). All geographical points (including strata boundaries and

transect start points) were marked out using a hand held GPS (Global Positioning System) unit (GARMAN, eTrex).

Within each stratum, one sampling transect was plotted out at a randomly generated distance from the southern stratum boundary. Transects were required to be at least 20 m apart, following Beentjes and Gilbert's (2006a,b) guideline. Each transect ran perpendicular to the shore and extended from the edge of cliffs/dunes down to low water. The survey was conducted during the spring tide period in December 2009 allowing the lower extent of the intertidal zone to be sampled. The survey was completed under customary authorisation (N^os SI 01984 and SI 01989).

3.2.3 Sampling Methods

Sampling methods were replicated from Beentjes & Gilbert (2006a,b). However the sieving technique was used for each of the 16 transects to ensure the greatest sampling of juvenile toheroa. Along the length of each sampling transect 0.5 m² (1.0 x 0.5 m) quadrats were positioned at 5 m intervals (Figure 3.2). All quadrats were excavated with spades to a depth of 30 cm and the sand was transported and sieved in the surf in trolleys lined with fine metal mesh (4 mm) (Fig 3.2). All toheroa collected in the trolley were weighed to the nearest 0.1 g and the length measurement taken along the longest shell dimension on anterior/posterior axis with vernier callipers was recorded to the nearest 1 mm (rounding downwards). After processing, toheroa were returned to the substrate in close vicinity to where they were excavated from. Transects extended into the spring low tide zone until no toheroa were found, thus ensuring that the lower boundary of the beds was sampled.

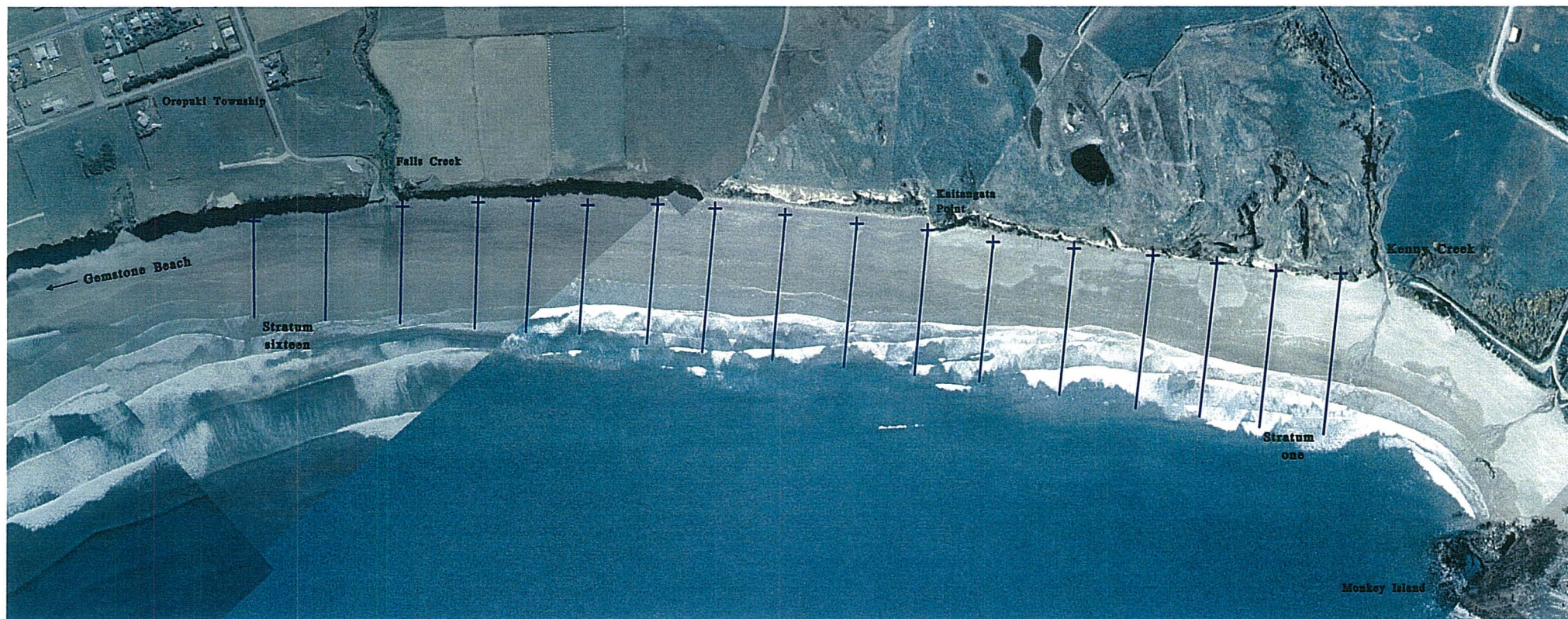
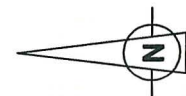
3.2.4 Statistical Analysis

A sparse and patchy distribution was observed, as is typical of toheroa beds in Murihiku. The majority of 0.5 m² quadrats sampled had no toheroa present in them, while some had much higher densities. The skewed distribution (i.e. from the inflated zero values; Martin *et al.* 2005) of the counts is not readily amenable to parametric statistical analysis even after severe transformation of the data (Fletcher *et al.* 2005; Martin *et al.* 2005). Therefore the average density of juvenile (≤ 39 mm), sub-adult (40-99 mm) and adult (≥ 100 mm) toheroa at Orepuki Beach with associated confidence intervals were estimated using non-parametric bootstrapping methods (Manly 2007; Chernick 2008). This computer-intensive technique

repeatedly re-samples observed counts (from the 428 excavated quadrats) to approximate a distribution from which parameters such as a mean and variance can be estimated. A total of 10,000 random re-samples were conducted from the observed counts with replacement. The 2.5th and 97.5th percentile bootstrap confidence limits around the means have been reported, which approximate the 95% confidence limits found by parametric methods. Abundance estimates for each size class were then generated by multiplying the density of the toheroa sampled by the total survey area (average transect length (135 m) x survey area width (1600 m)). Quadrat counts were also pooled across alongshore (i.e. inner and outer bed) and downshore (i.e. upper and lower) zones of the beach on which bootstrapping techniques were conducted to investigate the level of spatial variation in toheroa colony.

3.2.5 Substrate Analysis

Substrate type was qualitatively assessed for each quadrat following the seven categories outlined in Beentjes & Gilbert (2006a,b) of: 1) sand; 2) coarse sand; 3) sand and some gravel/stone; 4) sand and moderate gravel/stone; 5) sand and lots of gravel/stone; 6) sand and mainly cobble; 7) cobble.



Key:
— Strata boundaries

Scale: 1:8500
approximately

Figure 3.1. Strata positions of the 2008 Orepuki Beach toheroa population survey.



Figure 3.2. Surveying methods to assess the Orepuki Beach toheroa colony density and size structure, December 2008. a) excavation of 0.5 m² quadrats (visible in far right of photograph b)), with spades into the aluminium meshed trolleys c). d) illustrates the transect line of 5 m spaced excavated quadrats.

3.3 Results

The Orepuki Beach toheroa population was surveyed between the 14th and 23rd of December 2008. The current northern boundary of the colony was located at 46° 17' 03.90"S 167° 43' 57.65"E; and its southern extremity was at 46° 17' 51.66"S 167° 43' 48.54"E (World Geodetic System 1984). Low tide height during the survey period ranged from 0.64 to 1.36 m below mean sea level. A 1.6 km stretch of the beach was surveyed using 16 transect lines with a total of 428 quadrats. The number of quadrats per transect ranged between 20 to 30, giving an average transect length of 135 m. Details of the sampling design are given for each transect line in Table 3.1.

3.3.1 Toheroa abundance and density

Toheroa occurred in 188 (44%) out of the 428 excavated quadrats. The number of individuals for the three size classes sampled in each of the 16 transects are given in Table 3.1. Where present, toheroa occurred at densities ranging from one to 18 per quadrat.

The total population size at Orepuki Beach is estimated to be approximately 382,000 (95% CI 320,224 - 451,133) toheroa. Composed of approximately 240,000 juveniles (188,000-297,000); 84,000 sub-adults (95% CI 62,000 – 107,000); and 60,000 adults (95% CI 35,000 – 86,000) (Table 3.2a). Comparing these population estimates with the most recent accessible surveys elsewhere suggests that the adult population at Orepuki is approximately a third the size of the toheroa population at Bluecliffs Beach, and a tenth the size of the population at Oreti Beach (Table 3.2a). All of the Murihiku toheroa populations are much smaller than estimates for Dargaville Beach, representing a Taitokerau population (Table 3.2a).

The average adult density at Orepuki Beach was comparable to that obtained at Bluecliffs and higher than at Oreti Beach in 2005 (Table 3.2b, Fig. 3.3). Similarly there was a higher density of sub-adults at Orepuki Beach compared to that of the Bluecliffs and Oreti populations. Oreti Beach's larger adult abundance is the result of a relatively lower adult density being extrapolated across a much larger colony size (17 km at Oreti; 5.1 km at Bluecliffs; and 1.6 km at Orepuki).

Table 3.1. Sampling design details, total number of toheroa and density from each size class in each transect within the 16 strata at Orepuki Beach, December 2008. J = juveniles (≤ 39 mm); S = sub-adults (40-99 mm); A = adults (≥ 100 mm).

Stratum	N° of quadrats	Transect length	N° of toheroa per transect			Density (per m ²)		
			J	S	A	J	S	A
1	28	135	7	1	0	1.00	0.14	0.00
2	30	145	14	3	1	1.87	0.40	0.13
3	27	130	19	1	1	2.81	0.15	0.15
4	28	135	7	9	3	1.00	1.29	0.43
5	29	140	8	5	12	1.10	0.69	1.66
6	26	125	12	5	9	1.85	0.77	1.38
7	30	145	8	5	6	1.07	0.67	0.80
8	30	145	35	9	11	4.67	1.20	1.47
9	28	135	25	4	4	3.57	0.57	0.57
10	29	135	35	8	6	5.00	1.14	0.86
11	29	140	20	4	2	2.76	0.55	0.28
12	26	125	17	7	1	2.62	1.08	0.15
13	25	120	4	7	1	0.64	1.12	0.16
14	24	115	11	5	0	1.83	0.83	0.00
15	21	100	13	9	1	2.48	1.71	0.19
16	20	95	1	1	0	0.20	0.20	0.00

Table 3.2. Recent a) population size estimates; and b) density of juvenile, sub-adult and adult toheroa in Murihiku and Dargaville Beach (Taitokerau). Data for Orepuki Beach are from 2008 (present study); Bluecliffs Beach for 2005 (Beentjes & Gilbert 2006a); Oreti Beach for 2005 (Beentjes & Gilbert 2006b) and Dargaville Beach (Akroyd *et al.* 2008). Brackets show the 95% confidence intervals.

a)	Orepuki	Bluecliffs	Oreti	Dargaville Beach
Juveniles (≤ 39 mm)	238,333 (188,308-297,063)	805,670 (636,728-974,612)	6,981,762 (5,677,097-8,286,427)	55,436,432 (20,687,680-90,185,184)
Sub-adults (40-99 mm)	83,873 (62,434 – 106,741)	51,263 (27,262-75,264)	400,894 (250,034-551,754)	2,825,733[†] (2,338,612-3,312,854)
Adults (≥ 100 mm)	58,585 (35,245-85,594)	165,121 (117,734-212,508)	582,829 (480,735-684,923)	849,831[†] (675,933-1,023,729)
TOTAL	381,553 (320,224-451,133)	1,022,054 *	7,965,485 *	58,262,165 (23,492,804-93,031,526)

b)	Orepuki	Bluecliffs	Oreti	Dargaville Beach
Juveniles (≤ 39 mm)	1.10 (0.87-1.38)	1.44 (1.14-1.74)	2.00 (1.63-2.37)	10.94 (4.08-17.80)
Sub-adults (40-99 mm)	0.39 (0.29-0.49)	0.09 (0.05-0.13)	0.17 (0.13-0.21)	0.56[†] (0.46-0.65)
Adults (≥ 100 mm)	0.27 (0.16-0.40)	0.30 (0.22-0.38)	0.12 (0.09-0.15)	0.17[†] (0.13-0.20)
TOTAL	1.77 (1.48-2.09)	1.83 *	2.29 *	11.23 (4.36-18.08)

[†] Dargaville estimates sub-adults are classed as 41-75 mm and adults >75 mm following Akroyd *et al.* (2008).

* Estimates not available from source.

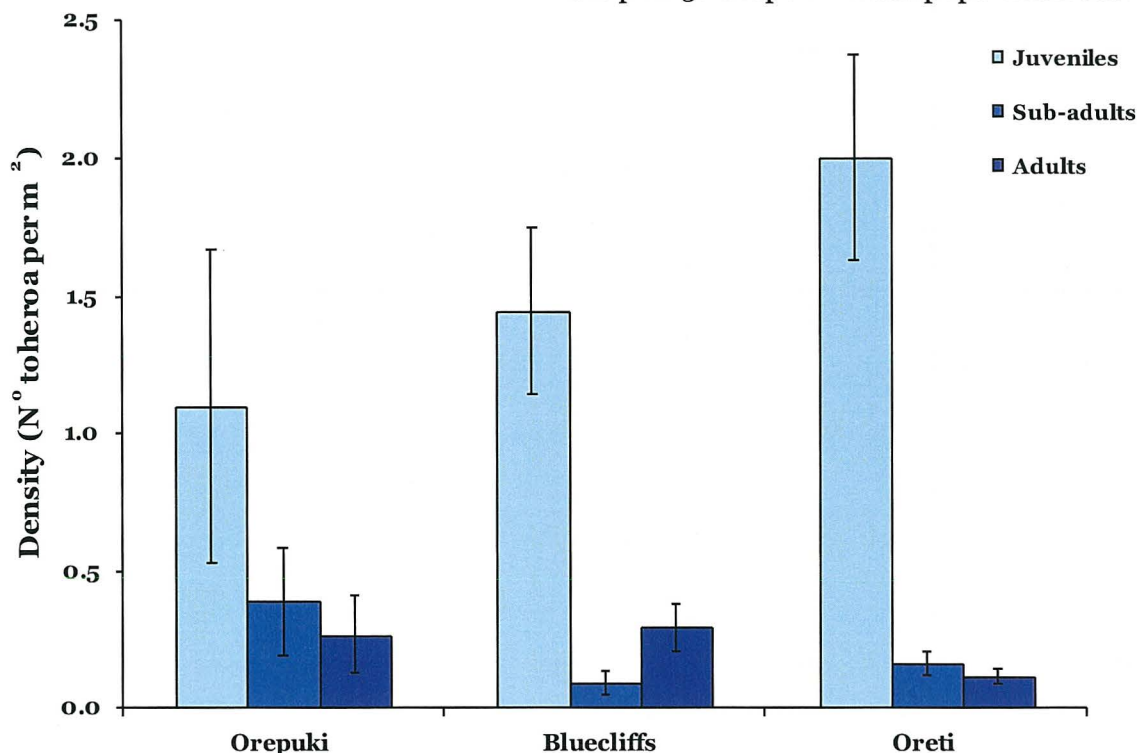


Figure 3.3. Density of juvenile (≤ 39 mm), sub-adult (40-99 mm) and adult (≥ 100 mm) toheroa for the three Murihiku toheroa colonies. Error bars represent 95% confidence intervals.

3.3.2 Toheroa distribution

Toheroa were present in all strata covering 1.6 km along Orepuki Beach. However, the adult size class was absent from the outer margins of the bed (strata 1, 14 and 16; Table 1). The three-dimensional distribution plots show that the toheroa bed is continuous, however, there are definable zones in which each of the different size classes dominated (Fig. 3.4). Juveniles had the largest and most evenly spread distribution across the beach, followed by sub-adults, whereas the adults were concentrated in the mid section of the beach (Fig. 3.4). This aggregation is also represented in the cumulative distribution plot showing over 80% of the adult toheroa occur within the 600 m between stratum 4 and 10 (Fig. 3.5). The toheroa bed thins out towards the edges of the sampling area with a significant higher density of toheroa in the central eighth strata compared to the outer strata (mean difference in density calculated as -0.37 m² (95% CI -0.57 - -0.19 m²; i.e. significant as confidence interval does not contain zero).

Similarly, the three size classes occupied different vertical zones between high and low water with adults being found closer to the ocean and centralised on the beach and juveniles broadly dispersed (Fig. 3.4; Fig. 3.6). Juveniles appeared first at an

average downshore distance of 43.13 m (overall mean downshore position of 75.20 m), sub-adults appeared first at an average downshore distance of 71.25 m (overall mean downshore position of 93.40 m) and adults appeared first at an average downshore distance of 104.62 m (overall mean downshore position of 113.00 m). Furthermore, juveniles had the widest vertical distribution with the largest average downshore range of 68.44 m followed by sub-adults with an average of 35.19 m and adults with only a 14.17 m average vertical range. All three size classes were found at significantly higher densities in the mid 50 m surveyed than the top 50 m (mean difference in density calculated as for juveniles: -1.60 m^2 (95% CI $-2.29 - -1.04 \text{ m}^2$); sub-adults: -0.64 m^2 (95% CI $-0.85 - -0.45 \text{ m}^2$); and adults: -0.15 m^2 (95% CI $-0.31 - -0.04 \text{ m}^2$). Adult toheroa were also found at significantly higher densities in the lower 50 m surveyed than in mid section (mean difference in density calculated as -0.70 m^2 (95% CI $-1.12 - -0.32 \text{ m}^2$).

3.3.3 Stock structure

The Orepuki Beach toheroa population consisted of 64% juveniles, 22% sub-adults and 14% adults. The proportion of sub-adults is much higher at Orepuki than recently observed at both Bluecliffs and Oreti and overall the Orepuki population has the “youngest” age structure (Table 3.3). The length frequency curve indicates a bimodal distribution with a strong juvenile group between 10-20 mm extending down to the low sub-adults numbers (40-50 mm) and a second less dominant mode also exists in the adult size class between 100-120 mm (Fig 3.7). The largest size observed was 124.00 mm and the average was 42.80 mm.

3.3.4 Substrate analysis

Of the 430 quadrats sampled, 94% contained fine sand, the remaining 6% were classified coarse sand. The coarse sand was situated in stratum 15 and 16, which both fell on the western side of the freshwater stream at the Orepuki beach access road. These two strata presented coarser, darker sand, particularly in the higher reaches of the beach. Furthermore, the beach profile was steeper, explaining the relatively shorter transects seen in strata 15 and 16. It should also be noted that some small stones were found dispersed amongst the lower quadrats at the western end of the survey area. These were found in very low abundance and therefore quadrats remained in the fine sand category.

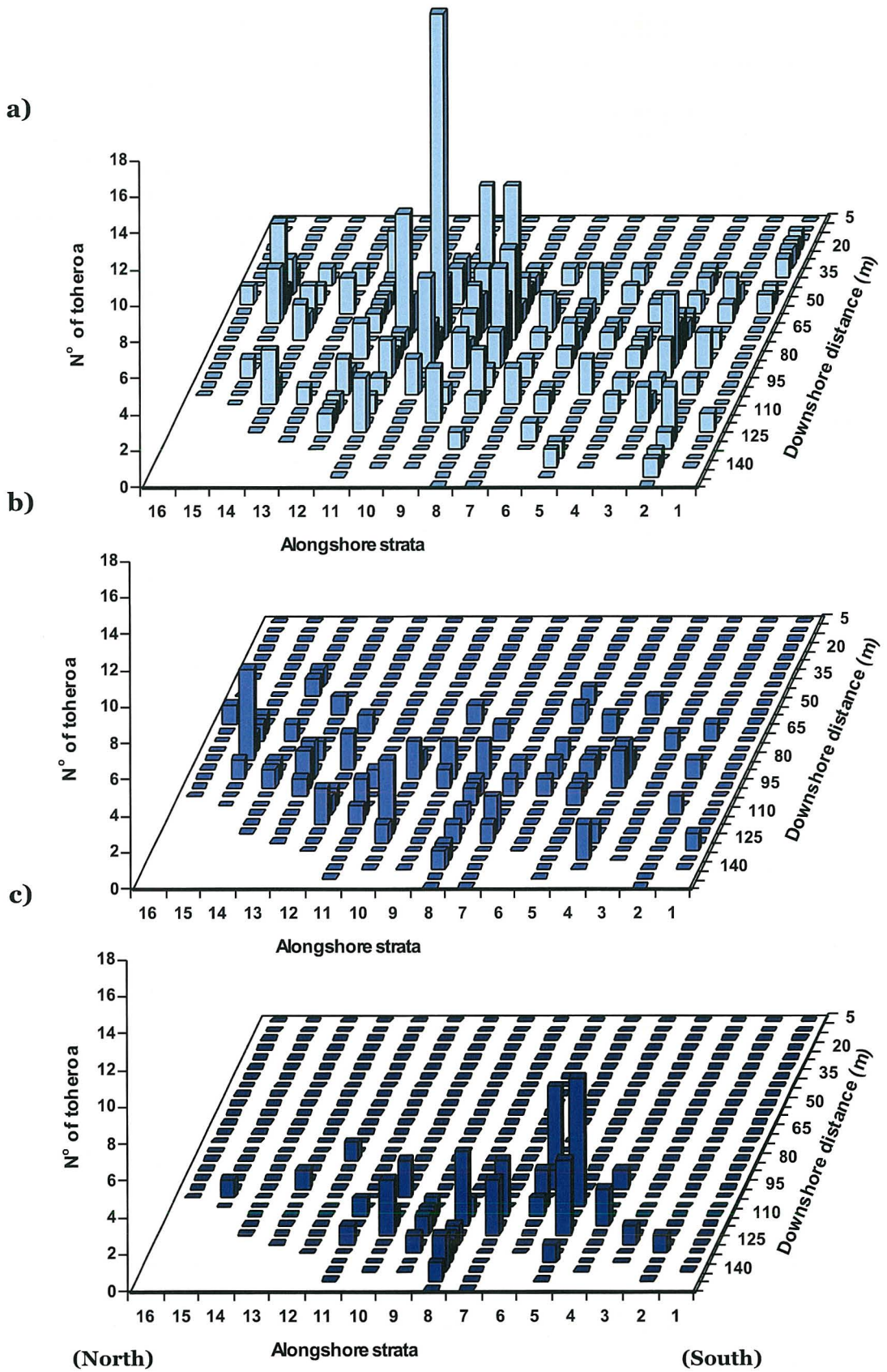


Figure 3.4. Three dimensional distribution plots of the number of toheroa sampled in each quadrat at Orepuki Beach December 2008 for a) juveniles; b) sub-adults; and c) adults.

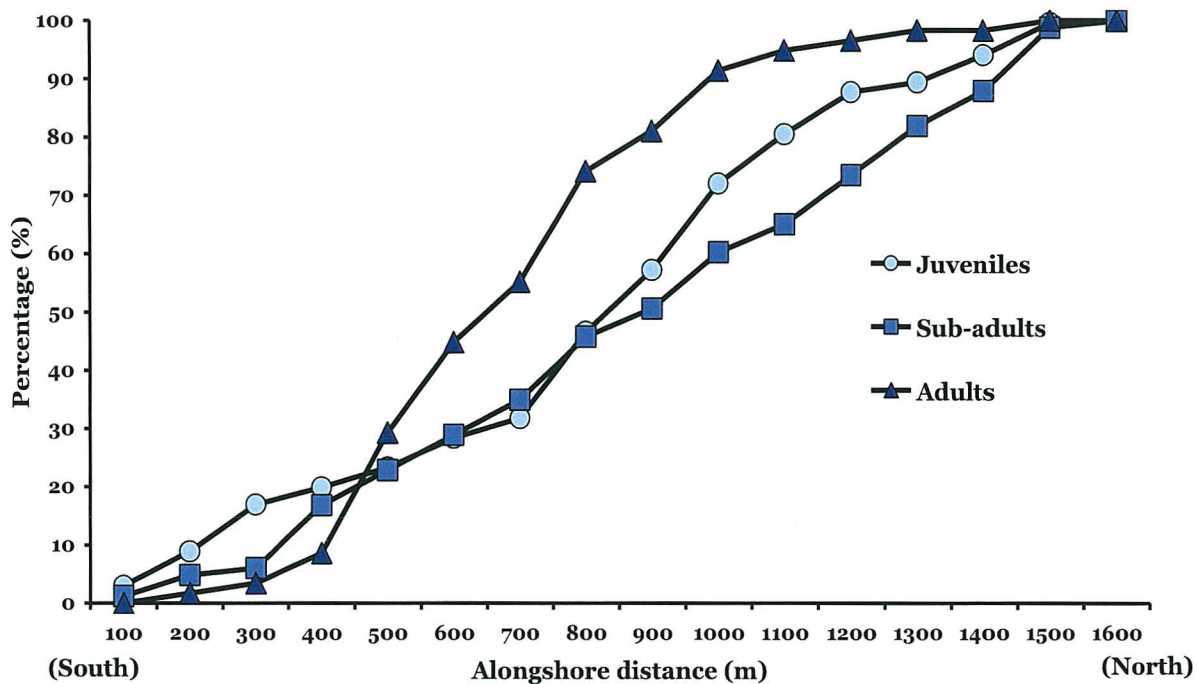


Figure 3.5. Cumulative distribution of toheroa along Orepuiki Beach from south (stratum 1) to north (stratum 16) for each of the three size class.

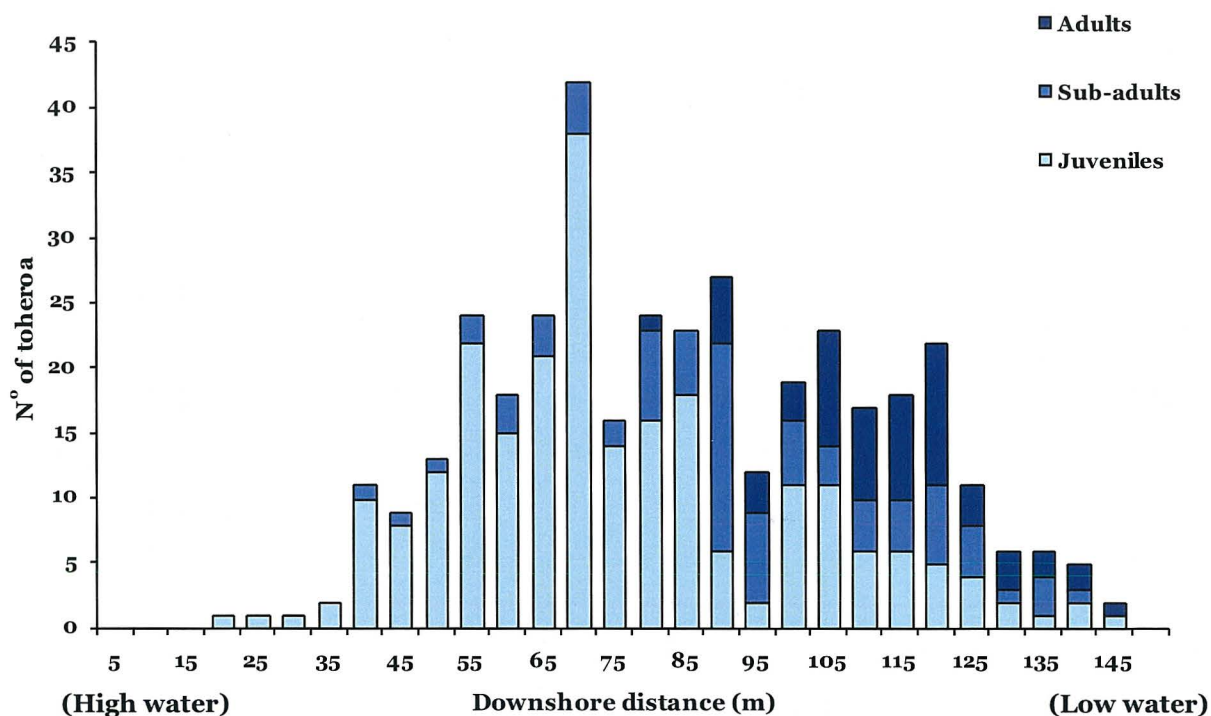


Figure 3.6. Total number of toheroa sampled in each size class down Orepuiki Beach (high water to low water).

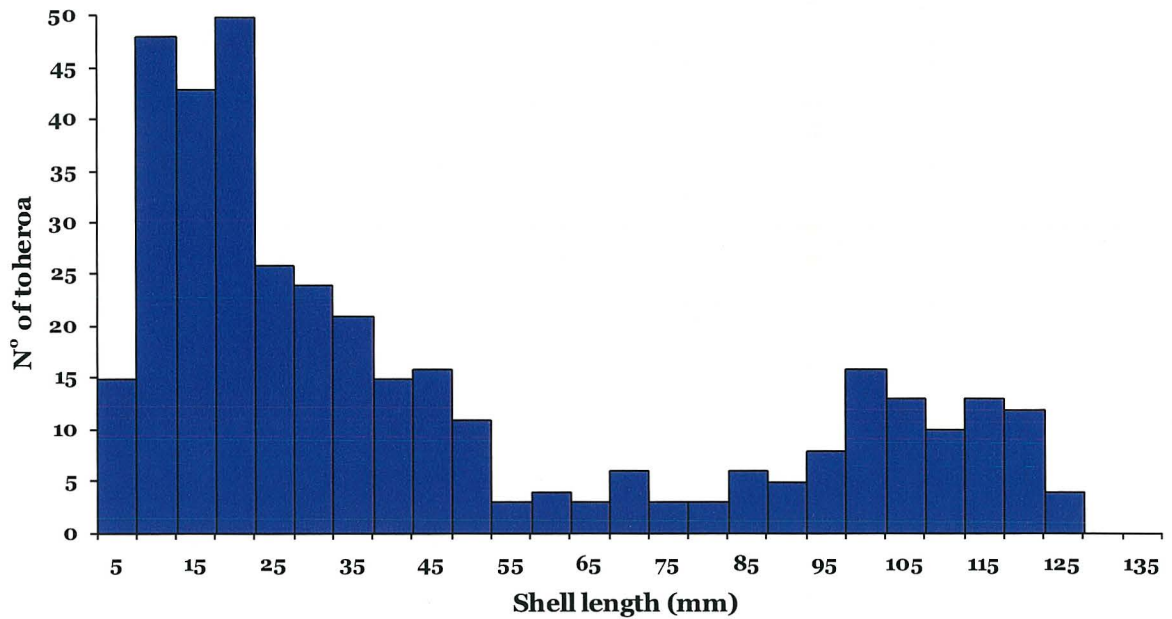


Figure 3.7. Size frequency distribution of all sampled toheroa at Orepuki Beach, December 2008.

Table 3.3. Latest size/age structure of the three Murihiku toheroa populations. Orepuki (present results); Bluecliffs (Beentjes & Gilbert 2006a); Oreti (Beentjes & Gilbert 2006b).

	Orepuki (2008)	Bluecliffs (2005)	Oreti (2005)
Juveniles (≤ 39 mm)	64%	50%	63%
Sub-adults (40-99 mm)	22 %	7 %	9%
Adults (≥ 100 mm)	14%	41%	27%

3.4 Discussion

3.4.1 Abundance and density

Over the past 50 years a healthy toheroa population has been established at Orepuki Beach from the original transplanting efforts of the local Te Waewae Bay community members. The translocation of adult toheroa to Orepuki Beach can be considered a success given that the founding individuals appear to have survived and recruitment is occurring. Due to the lack of previous surveys, comparisons with elements of the Bluecliffs and Oreti beaches' toheroa populations are the only means by which the Orepuki Beach toheroa population status can be assessed. The 2008 abundance of the juveniles, sub-adults and adults estimated at approximately 227,000, 80,000 and 56,000 respectively. The current Orepuki toheroa population is around a third the size of the latest estimated population at Bluecliffs Beach (Beentjes & Gilbert 2006a) and a tenth the colony at Oreti Beach (Beentjes & Gilbert 2006b).

Comparison of densities provides a complementary, and in some respects better indicator of how well a resource is performing ecologically than its total population size. Evaluating the 2008 Orepuki Beach density estimates against the 2005 estimates of Bluecliffs and Oreti suggest that the ecological conditions are comparable if not better at Orepuki Beach. However, the newly founded population's overall contribution to the Murihiku toheroa meta-population is constrained mainly by its comparatively smaller total area. The smaller toheroa bed dimensions at Orepuki Beach may be explained by the relatively short establishment period (i.e. approximately 50 years since first translocation event).

The low density of juveniles observed at Orepuki Beach may be explained either by the survey occurring earlier in the breeding/spawning season than the other two surveys or by lower reproductive output than the Bluecliffs and Oreti colonies. The Taitokerau toheroa beds have always been regarded as the 'main' stocks within New Zealand with higher numbers and densities and faster growth rates than those toheroa found elsewhere (Cassie 1955; Redfearn 1974). The most likely explanation for the difference between the toheroa stocks throughout their range is that the Taitokerau populations occupy beach in sub-tropical areas, and thus are exposed to warmer temperatures.

The Orepuki Beach population can be regarded as a considerable safeguard of the Te Waewae Bay toheroa should the Bluecliffs Beach population collapse. Efforts for further enhancement of the Orepuki Beach population could include translocation of more individuals within the current bed and into the uninhabited northern extent of the Orepuki Beach. Likewise, the establishment of new populations around Murihiku would greatly increase the resilience of this taonga with Murihiku. The success of these efforts will revolve around habitat suitability of receiver sites. It is suggested that cautious attempts (i.e. low sample sizes) at translocation should be implemented to conduct trial translocations to test the suitability of the most likely receiver sites within Murihiku.

3.4.2 Distribution

The Orepuki Beach toheroa are situated in one distinct, continuous bed along the length of the survey area. Successful recruitment has occurred along the full extent of the survey area. However, aggregations of the larger toheroa are prominent in the mid section of the beach. Both the along and downshore distribution of the toheroa are size dependent, creating distinct zones in which each size class predominates. This zonation of the size classes appears to be a common characteristic of toheroa populations as seen at both Bluecliffs Beach (Beentjes & Gilbert 2006a) and Oreti Beach (Beentjes & Gilbert 2006b) and is the result of the larger toheroa being able to successfully exploit the lower beach where the wave conditions are more intense (Kondo & Stace 1995). The lower shore position ensures longer submergence and feeding times. The wide vertical zone occupied by the juveniles is the result of them continually drifting and being redistributed in the ebbing waves (Redfearn 1974).

The highly aggregated adult toheroa observed in the Orepuki Beach population is common in previously surveyed toheroa (Beentjes & Gilbert 2006b). The nature these aggregations is not entirely understood. Interviewee W offered his insight:

“They are competing and so there is a bit of a contradiction there, a paradox. Why would you want to compete when you can move along the beach and have the water mass that you are filtering completely to yourself. It’s a lot more complicated than that and probably clearly beaches have certain characteristics about where the best place to be is on a beach in terms of feeding and that’s undoubtedly effecting their distribution. We don’t know the answer to that”.

Similarly Cassie (1955) concluded the over-dispersing nature is probably being dictated by heterogeneity in environmental conditions of the beaches. The lack of dense adult beds present in the outer regions of the survey area could be a result of poor recruitment success in these sections or the active migration of adult toheroa into the mid section of the beach. The benefits of this migration could be to occupy the most suitable habitat on Orepuki Beach or it may serve as more of a functional role for the persistence of the species (i.e. to facilitate successful fertilisation given the mass spawning nature of the toheroa).

Interestingly, the aggregation of the adult toheroa observed in this present study is occupying the area around where toheroa were released in the mid 1950s. However, the toheroa released around Falls Creek, at the Orepuki Beach access road in the mid 1970s are not present in the same relatively high density. Although toheroa density is often elevated in the vicinity of freshwater (Rapson 1952; Redfearn 1974), they may have been placed too close to the stream and migrated alongshore to more favourable habitat, or alternatively the latest translocation may have failed.

3.4.3 Stock structure

To ensure the population will persist, a high representation of all three size classes are vital (Berkely *et al.* 2004b). The presence of a solid breeding stock helps ensure recruitment will occur. The large proportion of smaller toheroa, of which a large majority will hopefully successfully reach maturity, will contribute to the breeding potential of the colony. The Orepuki Beach population resembles a population structure typical of toheroa beds, dominated by a high proportion of juveniles and a second strong adult mode (Beentjes & Gilbert 2006a,b). The 'newly' established population differs from the stock structures of the Bluecliffs and Oreti colonies as it has a higher proportion of sub-adults and a lower maximum size. The maximum size sampled at Orepuki Beach in 2008 was 10 mm less than that sampled at Oreti (Beentjes & Gilbert 2006b) and 30 mm less than that sampled at Bluecliffs (Beentjes & Gilbert 2006a).

The stock structures presented in Table 3.3 provide evidence that the Bluecliffs population is potentially facing recruitment failure with a considerably lower proportion of juveniles, whereas the Orepuki population presents similar proportions of juveniles as the Oreti Beach toheroa colony. However, Orepuki Beach has an approximately three times larger proportion of sub-adults than observed at the other

two toheroa colonies. Beentjes & Gilbert (2006a) described the lack of the sub-adult mode as being a “distinguishable feature” of the 2005 Bluecliffs toheroa population however the conditions at Orepuki Beach have led to the development of a differing stock structure. There are two primary explanations for the increased sub-adult mode in the Orepuki Beach toheroa population. Firstly the large presence of juvenile and sub-adult toheroa could be the result of several successive spawning events in the recent past, which is transcribed into the younger population structure presented. In order to determine if this high proportion of immature individuals is going to contribute to population growth, regular periodic surveys (1-3 years) will need to be conducted to allow comparisons with the base line data collected in this present study (Beentjes & Gilbert 2006b). The large proportions of sub-adults could also be a result of the toheroa at Orepuki Beach experiencing lower growth rates than those at Bluecliffs and Oreti beaches. If the toheroa recruits are not reaching adult sizes as quickly, there is the possibility that the sub-adult group is made up of cumulative cohorts and thus contain a higher proportion of breeding individuals.

A reduced growth rate and/or a lack of reaching maximum sizes could be the result of a single or combination of biotic and abiotic factors. An investigation into nutrient supplies from the surrounding freshwater inputs and pelagic system would assess the main food source supply for the Orepuki Beach toheroa and help determine if this is a limiting factor. Other possible factors influencing the growth rate of the Orepuki colony may include pollution and temperature variations (Griffin 1995). Alternatively it is possible that the adults transplanted to Orepuki Beach did not provide a complete representation of the genetic diversity available in the Bluecliffs Beach population (i.e the larger individual's genes were not represented). However, this conclusion is unlikely if all of the reported transplanting efforts to Orepuki Beach were successful. This discussion highlights the importance of having a large enough founding population to ensure a high degree of genetic diversity is present when attempting to establish new populations via translocations. Ensuring maximum genetic diversity in a founding population will help guarantee the new stock's success in establishing and future population growth (Soule *et al.* 1986).

3.4.4 Reproductive potential

No spatfall was observed during the Orepuki Beach population survey. However, the high presence of juveniles within the population provides evidence that some

recruitment is occurring. To determine the level of recruitment, a long term study with annual surveys would be preferable. The more frequent the surveys the more knowledge can be gained on the variation in spat production, recruitment success and mortality of individual cohorts.

In order for successful recruitment, (i.e. the spat to be reintroduced to the parent source beach), a circular current system is required. It is assumed this is occurring at Orepuki Beach, however, we can not be entirely certain that is the case. Given the reduced flow of the Waiau River, there is the possibility that Orepuki Beach is no longer isolated from spat sourced from Bluecliffs Beach. If the Orepuki Beach toheroa population is not self-seeding and the recruits are in fact being sourced from the Bluecliffs Beach population, the loss of a successful breeding population at Bluecliffs Beach would also lead to the local extinction of toheroa from Orepuki Beach. A survey testing the genetic relatedness of juvenile toheroa to the adults present at each of the two Te Waewae Bay colonies would need to be conducted to investigate the parent source of the Orepuki Beach recruits.

The higher presence of the sub-adult size class coupled with the reduced maximum size raises a question whether the Orepuki Beach toheroa are reaching sexual maturity at relatively smaller sizes (i.e. <75 mm). It is not known whether toheroa maturation is triggered by overall size, age, or a mixture of both. Should the size of sexual maturity of the Orepuki Beach population deviate from the expected toheroa model, the current harvest management would become inappropriate. The lack of individuals in the larger adult size range is also worthy of being investigated as the lower proportion of adults could mean that the total reproductive potential of the population is significantly hindered. Size at sexual maturity and the fecundity levels of various size classes need to be investigated to help assess the reproductive success of the newly established population. If the Orepuki Beach population is not self-seeding then more intensive enhancement measures, such as the rearing and releasing of spat, may need to be considered.

3.4.5 Habitat suitability of receiver sites

Interviewee W described Oreti Beach as being the model of an ideal habitat for toheroa:

“Well, if you look at Oreti Beach it is a perfect habitat. It has fine sand, it has a very gentle slope, it has a wide inter-tidal zone. Now if you contrast that with Bluecliffs, which is quite steep, steeper now than it used to be, it doesn’t have as much sand and it has coarse material over the beach”.

Orepuki Beach more closely resembles these characteristics of Oreti Beach, as did Bluecliffs Beach before 1970. All sampling quadrats consisted of either fine sand (substrate type one) or coarse sand (substrate type two). However given the presence of the few randomly dispersed stones it can be assumed that the sand cover at Orepuki Beach is much greater than Bluecliffs Beach, but perhaps not as deep as that of Oreti Beach. The northern 200 m of the survey area presented marginally lower densities of toheroa and the presence of much coarser sand. It remains unclear whether this decrease in toheroa density is the result of the less suitable habitat of whether the bed is naturally less dense around the boundaries. Moreover, sandy beaches are dynamic systems and the composition of the substrate in strata 15 and 16 may change through different phases (particularly following storm events) becoming more or less suitable to the toheroa in those two zones over time.

The presence of toheroa beyond the northern reach of Orepuki Beach was repeatedly checked during the survey period, using the siphon hole counting technique (Metzger 2007; refer to Chapter 4) to ensure the full extent of the bed was included in the survey. No siphon holes were found between the western boundary of stratum 16 and the neighbouring Gemstone Beach. However juvenile recruitment in the upper zones of the beach was not checked in the ebbing waves, in which juveniles appear on the surface of the sand. The coarser, darker sands become more concentrated towards Gemstone Beach, however if the toheroa could successfully survive in the coarse sands of stratum 15 and 16 there is potential for the extension of the Orepuki Beach population in this currently uninhabited area.

3.4.6 Future Management

Following this present study, the kaitiaki of Te Waewae Bay now have access to information about the Orepuki Beach toheroa population and can move on to decide how best to manage it. Decisions will include how they wish to distribute harvest pressure between the two beaches (Bluecliffs and Orepuki). Questions about whether to reserve either beach as an un-harvested reference beach or to allow equal harvest pressure, needs to be addressed. The present study has shown that translocation of

toheroa to a novel beach can result in the development of a new stock. It has also highlighted the need to understand the factors that may be limiting the growth of the Orepuki Beach toheroa. Future research into source of recruits and population growth rate are needed to fully understand the success of the translocation efforts to Orepuki Beach. Investigation into age/size at sexual maturity will also be key in understanding how to best manage the population. Future enhancement efforts of the stock could also increase the 'newly' established colony's reproductive potential. Lastly, poaching, traffic and predation need to be considered for investigation as being the major threats identified in the interview discussions (Chapter 2).

The origin of the Orepuki Beach toheroa population has clearly illustrated the potential use and value of traditional management techniques regarding the Murihiku toheroa. The wealth of knowledge surrounding the habitat requirements of toheroa coupled with desire to enhance the stocks available can now be built upon to enhance the resilience of the Murihiku toheroa meta-population. The kaitiaki of Taitokerau have spent the last 20 years developing enhancement techniques based on the translocation of toheroa (Akroyd 2002). Knowledge sharing between the groups could prove very valuable for ensuring the resilience of the Murihiku toheroa stocks.

CHAPTER FOUR

Calibration of a traditional monitoring tool: assessing density from toheroa siphon activity

“They are using shovels and forks to dig up the toheroa - if that doesn’t scrunch up the small ones I would love to know what does! No, the scientific survey method does not impress me at all”

Interviewee D

4.1 Introduction

Accurate monitoring regimes ensure resource managers have sufficient knowledge to manage natural resources in sustainable and effective ways (Sutherland 2006). Population surveys provide essential information regarding stock abundance, structure, distribution and recruitment success. The response of ecological communities and populations to environmental change and active management interventions is best assessed through the applications of regular monitoring methods that are statistically reliable, repeatable and if possible inexpensive. Often environmental managers cannot afford full census or ‘absolute density’ measures like number per square meter. Instead they are often forced to use indirect or ‘relative index’ measures of assessing abundance. Monitoring is fundamentally important for adaptive management approaches (Walters 2007) for learning how to sustain natural resources and protect ecological integrity of ecosystems and communities.

Indigenous peoples develop relative indicators to monitor wildfood populations to dictate sustainable harvesting. Traditional ecological monitoring methods have been shown to successfully complement modern monitoring regimes (e.g. Moller *et al.* 2004). However, cross-cultural partnerships and ethical considerations can sometimes make scientific research and monitoring slower, less precise and potentially less well replicated (Kitson & Moller 2008, Moller *et al.* 2009c). For example, a strict tikanga prevented researchers of tīti to visit islands at the most appropriate times to estimate sustainability and from digging the ground to calibrate their monitoring methods. Many of the interviewees contributing to this present study (refer to Chapter 2) emphasised a traditional teaching that only hands (or feet)

are to be used when harvesting toheroa. This tikanga was derived to protect the resource from disturbance and mechanical damage during harvesting. Several kaitiaki expressed concerns about the current monitoring regime, as the excavation styled surveys (refer to Chapter 3 for details) do not adhere to the traditional teaching and could be negatively impacting the toheroa populations. Informant D expressed his opinion of the current monitoring system by saying:

“They are using shovels and forks to dig up the toheroa - if that doesn’t scrunch up the small ones I would love to know what does! No, the scientific survey method does not impress me at all”

Informant T reasoned that if there is a less destructive way to survey and monitor the toheroa populations then this should be used:

“Oh yeah, no you shouldn’t dig unless you’re absolutely very, very careful - I’m not keen on it. We were talking about damage being done to the toheroa. Once you crack that shell then its bugged isn’t it? If there is a less destructive way then let’s do that” (Interviewee T).

An increasing number of scientific studies are concerned with the development of non-destructive indices to determine the size of benthic populations. In the marine environment this has largely been applied to cryptic and burrowing invertebrates to increase the feasibility and decrease environmental disturbance of population surveys (McPhee & Skilleter 2002). Butler & Bird (2007) recommend that less intrusive monitoring techniques be developed, especially for sensitive zones such as marine protected areas. The most common indirect measures of macroinvertebrate abundance on sandy shores are the counting of burrow holes/openings or the number of active individuals present on the beach surface. Such indices have been investigated for the fiddler crab (*Uca tangeri*; Jordoa & Oliveira 2003), ghost shrimps (*Trypaea australiensis* and *Biffarius arenosus*; Bird & Butler 2007); estuarine crab (*Heloecius cordiformisi*; Warren 1990), yabby (*Trypaea australiensis*; McPhee & Skilleter 2002); and propeller clam (*Cyrtodaria siliqua*; Gilkinson 2008).

Following from the above argument, several of the local kaitiaki expressed their desires to develop the traditional searching tool for identifying toheroa into a monitoring tool. The traditional searching method used when harvesting toheroa is to walk backwards parallel to the water (generally on an incoming tide). As the

toheroa are disturbed they will withdraw their siphons giving away their position (Metzger 2007). The presence of a toheroa can be determined by observing the siphon tips directly or by the dual depressions in the sand that are created with the retraction of the feeding/excretion apparatus (collectively hereafter referred to as siphon activity; Fig. 4.1). This chapter evaluates the utility of counting siphon activity as a non-invasive method of monitoring the abundance and distribution of toheroa. As the proportion of toheroa feeding at any one time will vary with weather, location, age/size of the toheroa, season or year, the siphon counting technique must be considered a relative index of absolute abundance. The primary goal of this study was to test whether the detection and counting of siphon activity can reliably index toheroa distribution, abundance or both. A 'best practice' protocol describing under which conditions the use of siphon activity can detect the presence/absence of toheroa was also explored.

The foremost important step in developing an indirect monitoring tool such as siphon activity is to assess its ability to accurately predict the absolute density of the animals (McPhee & Skilleter 2002). The aim of this study was to:

1. Investigate the validity of the traditional monitoring methodology of siphon activity counting as a reliable indicator of toheroa density across the three Murihiku toheroa colonies.

The siphon activity counting technique was assessed based on its power to successfully predict the absolute density of toheroa measured in the excavation surveys. A secondary aim included:

2. Assessing the use of detecting siphon activity for determining the presence/absence of toheroa in an area.

4.2 Methods

The completion of the excavation surveys at Orepuki, Bluecliffs and Oreti beaches during summer/autumn 2008/2009 provided the opportunity to independently validate the density estimates of the siphon activity indices against absolute density (i.e. density estimate from excavation surveys). Direct comparisons are essential in assessing the predictive power of such abundance indices (Eberhardt & Simmonds

1987; Stephens *et al.* 2006). The calibration of this present study was limited due the temporal differences in the completion of the excavation and siphon activity surveys.

4.2.1 Absolute toheroa density

Direct toheroa counts were derived from the excavation survey at Orepuki Beach (December 2008, Chapter 3), and those excavation surveys conducted by Dr Mike Beentjes and the NIWA team at Oreti Beach (February 2009) and Bluecliffs Beach (March 2009). As juvenile toheroa's siphons are small and inconspicuous in the sand, only the density estimates of the non-juvenile (i.e. sub-adult and adult; ≥ 40 mm) toheroa were used to generate these densities based on observed siphon activity.

4.2.2 Siphon activity counting index

Exposed inhalant siphon tips are circular filters, grey or orange in colouration and exhalent siphons are a narrower tube with a clear opening (Fig. 4.1a). The siphon holes that are created are distinct and easily recognisable as a dual depression, with the depression of the inhalant filtering siphon being the larger of the two holes (Fig. 4.1b). Toheroa also excrete pseudofaeces (undigested particulate matter) in a string which can aid in confirming a siphon hole after the siphons have retracted (Fig. 4.1). No other bivalve species were observed within the study areas during the excavation surveys at any of the three beaches (Chapter 3; M. Beentjes pers. comm.) and thus it was reasoned that any siphon activity sighted within the survey areas was associated with a toheroa.

Visual counts of siphon activity (extended siphon tips and/or siphon holes) were conducted by walking backwards parallel to the water line across the Orepuki, Bluecliffs and Oreti Beach survey areas. The survey areas were repeatedly traversed in order to cover a range of shore heights. The total length of Orepuki (1.6 km) and Bluecliffs (5 km) beach's survey areas were traversed. However, given the sheer extent of the Oreti Beach survey area (17 km), siphon activity counting was only conducted for approximately 4 km (i.e. 50 m either side of each transect line was surveyed). Figures 4.2-4.4 illustrate the positioning and intersecting of all the transect lines conducted during the two monitoring techniques.

The horizontal transects along which the siphon activity was counted were conducted in the saturated zone at the fringe of the water line. This ensured siphon activity was

surveyed at a constant shore height in relation to the proximity of the tide. The density of the toheroa was calculated as the number of siphon tips/siphon holes observed over 1 m wide transects either side of the observer for every five backward paces along the length of the horizontal transect. The position of the observer was recorded at every 25th step with a hand held global positioning system (GPS) unit (GARMAN eTrex). The pace was kept slow but steady across all densities of the toheroa beds to ensure no bias in the observation rates.

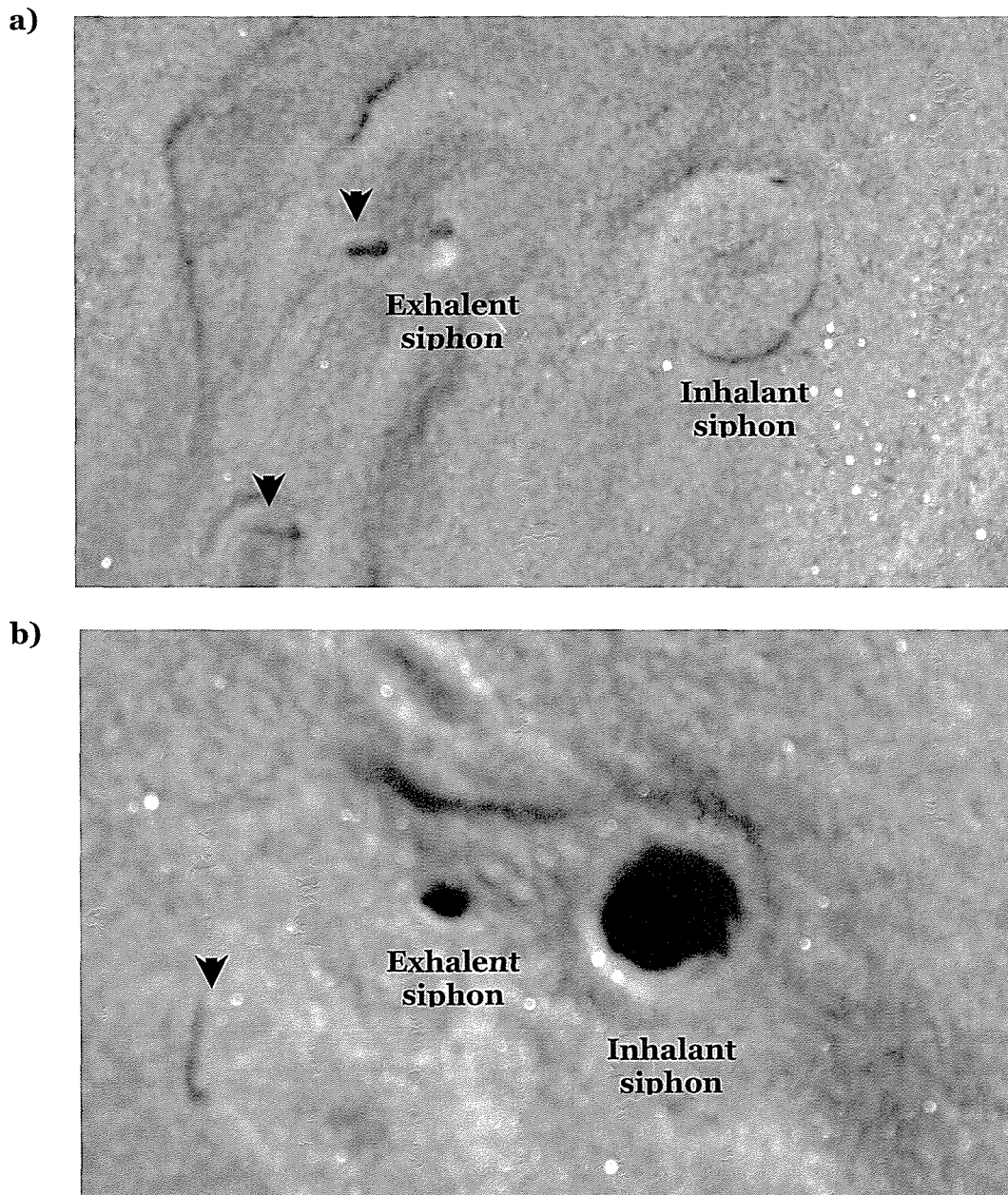


Figure 4.1. Siphon activity: a) toheroa siphon tips extended at surface; b) toheroa siphon holes, the characteristic dual depressions left in the sand from the retraction of the siphons. Pseudofaeces are indicated by the arrowheads. Inhalant siphon hole is approximately 8 mm in diameter.

4.2.3 Calibration of quadrat and siphon activity surveys against each other

To investigate the relationship of the average toheroa density generated from the two methods, estimates made at the intersection points of the vertical (excavation) transects and the horizontal (siphon activity counting) transects were compared directly (refer to Fig. 4.2-4.4). For each of the three beaches, only the density estimates from the areas in which non-juvenile toheroa (≥ 40 mm) were found were included in the analysis. The densities from both monitoring techniques included from a shore height of 100 m to low mean water were included at Oreti Beach and similarly from 40 m and 50 m for Orepuki Beach and Bluecliffs Beach respectively.

Given the patchy and variable nature of toheroa, many of both the paired quadrat counts and siphon activity counts were zeros. In order to allow successful analysis of the relationship between the density estimations, the spatial scale was set at comparing the average toheroa density from 75 steps surrounding the intersection point with the average toheroa density from the surrounding three quadrats (i.e. the quadrat closest to the intersection point and one from above and below covering a shore height of 15 m).

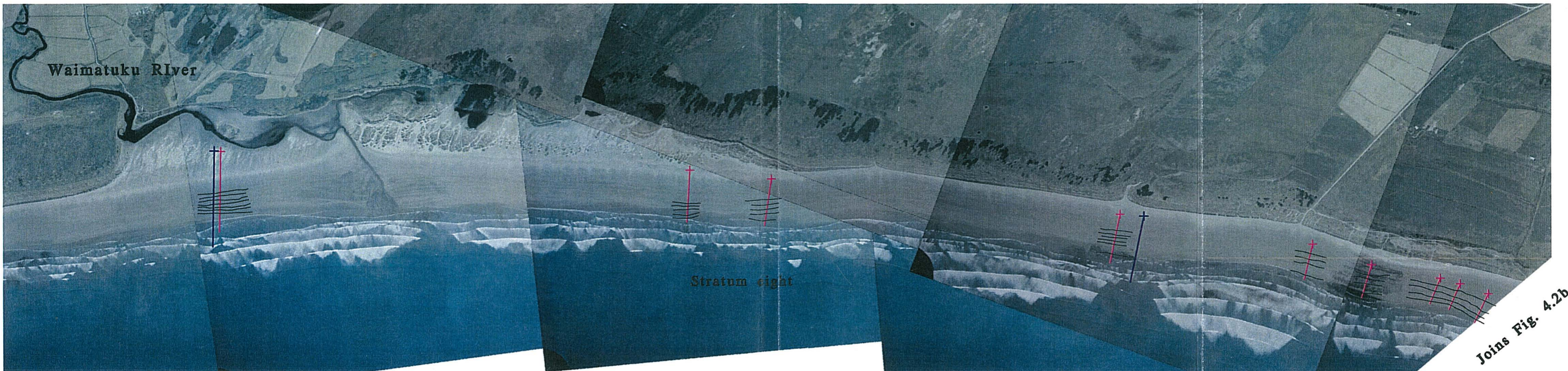
Weather conditions are thought to determine the proportion of toheroa with extended siphons at any one time (Interviewee A; Greenway 1969). Therefore the variation in the siphon activity predictability power was assessed across a range of climate conditions. Sand temperature was measured with a 100 mm temperature probe (Type K, Thermocouple thermometer; Digi-Sense®) in the saturated sand at the fringe of the water line. Air temperature and wind speed were measured with a handheld portable weather tracker (Kestrel 4000; Nielsen-Kellerman) and cloud cover was assigned a grade between 0 and 10, zero being no clouds and 10 being 100% cloud cover.

4.2.4 Statistical model building

Multi-linear regression models were applied to investigate the influence of beach site (i.e. Oreti, Orepuki and Bluecliffs), air and sand temperature, wind speed, cloud cover and tide direction on the relationship between the absolute toheroa density from the excavation surveys to the density estimates generated from the siphon activity

counting. Multicollinearity of the predictive variables was first explored to test assumptions of multiple regression modelling. A high level of multicollinearity between the predictors reduces the power of the analysis as the individual importance of each predictor becomes difficult to assess (Field 2005). Multi-linear regression models were then fitted to pooled data for all three beaches and then for each separate beach using Minitab (Version 15). Appropriate transformations were applied to the data to ensure that the assumptions of normality and homoscedasticity were met. The appropriateness of the models were explored with a backward stepwise approach to distinguish the best suite of predictors and most parsimonious model.

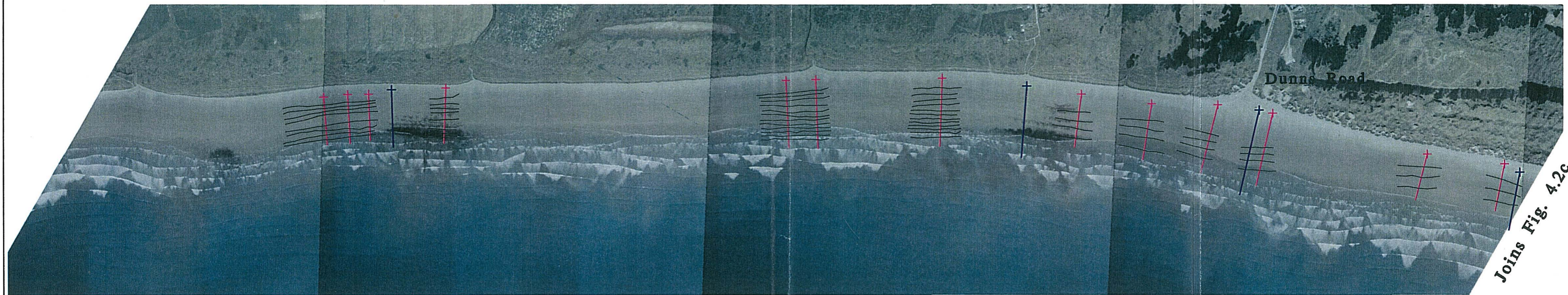
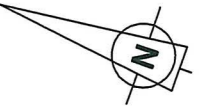
Further multiple logistic regression models were applied to determine under what conditions of weather and absolute abundance could you be certain to detect *Toheroa* from seeing at least one case of siphon activity in a transect conducted in the lower two thirds of the intertidal zone (i.e in the non-juvenile territory). From this a standardised protocol was developed detailing under what conditions the siphon activity searching technique should be applied in order to ensure the highest probability of detection.



Joins Fig. 4.2b

Key:	
—	Strata boundaries
—	Transect lines
—	Siphon counting transects

Figure 4.2a. Transects of the excavation survey and siphon activity counts within the north-western section of the Oreti Beach survey area.

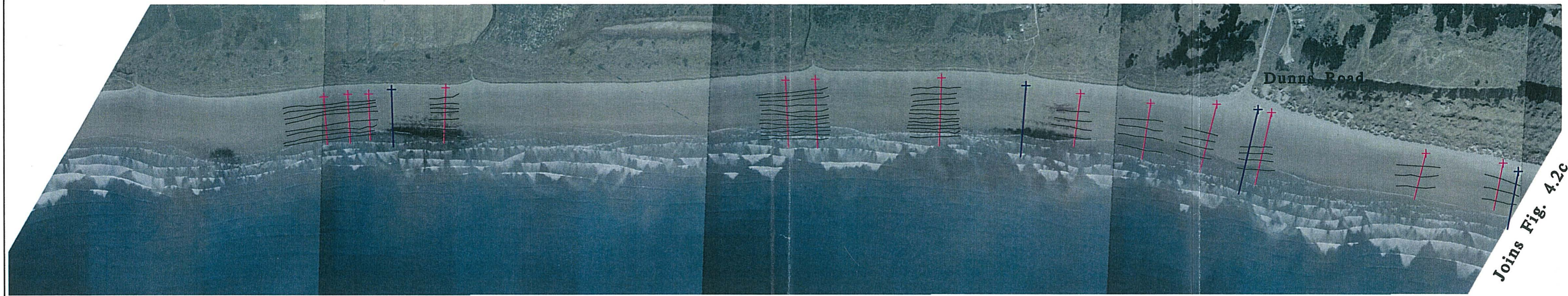
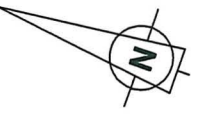


Joins Fig. 4.2c.

Key:

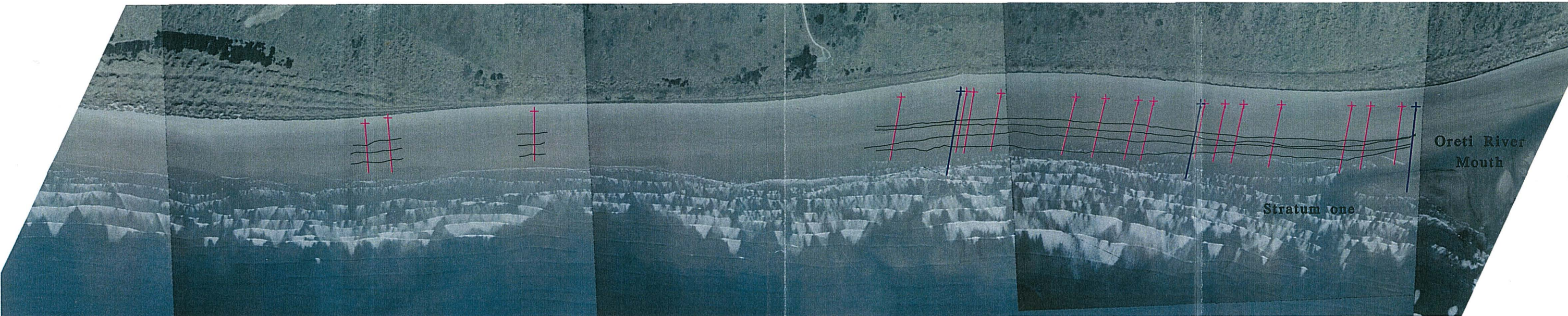
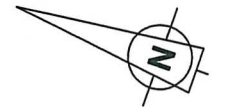
- Strata boundaries
- Transect lines
- Siphon counting transects

Figure 4.2b. Transects of the excavation survey and siphon activity counts within the mid section of the Oreti Beach survey area.



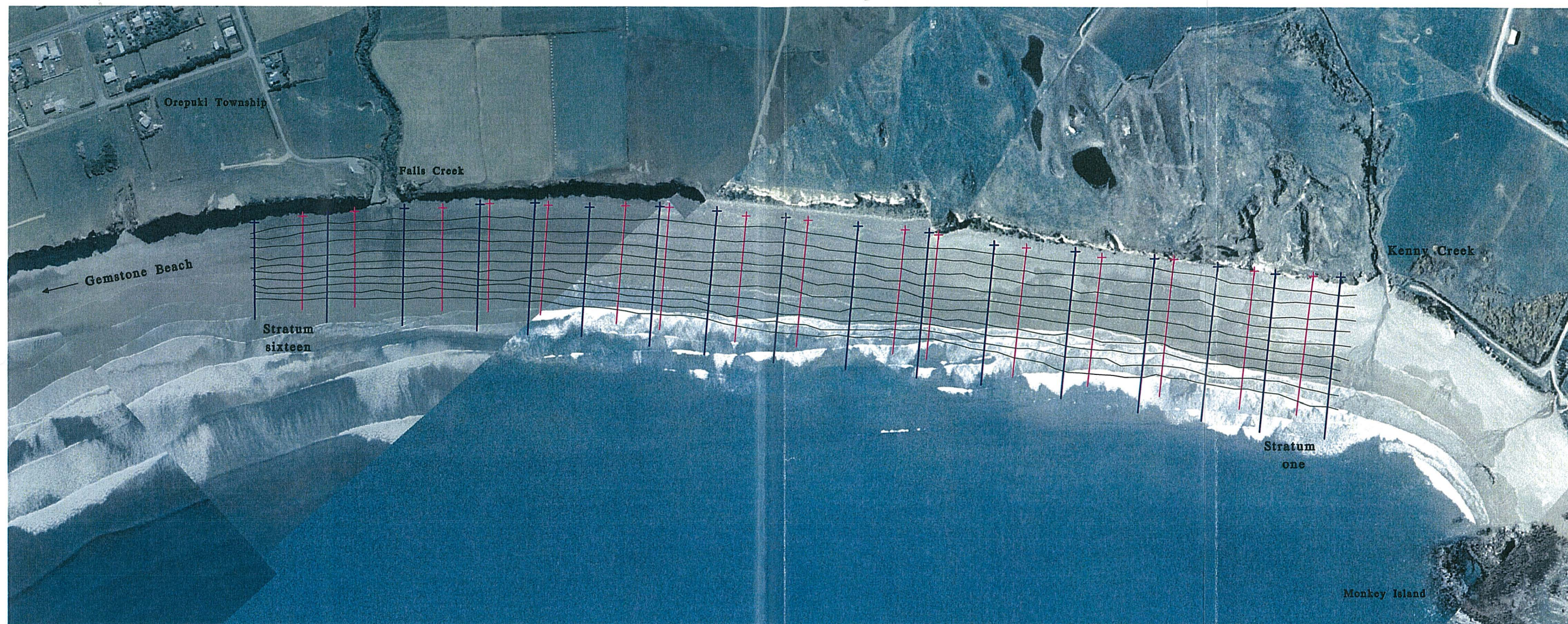
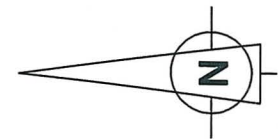
- Key:**
- Strata boundaries
 - Transect lines
 - Siphon counting transects

Figure 4.2b. Transects of the excavation survey and siphon activity counts within the mid section of the Oreti Beach survey area.



- Key:**
- Strata boundaries
 - Transect lines
 - Siphon counting transects

Figure 4.2c. Transects of the excavation survey and siphon activity counts within the south-eastern section of the Oreti Beach survey area.



Key:

— Strata boundaries

— Transect lines

— Siphon counting transects

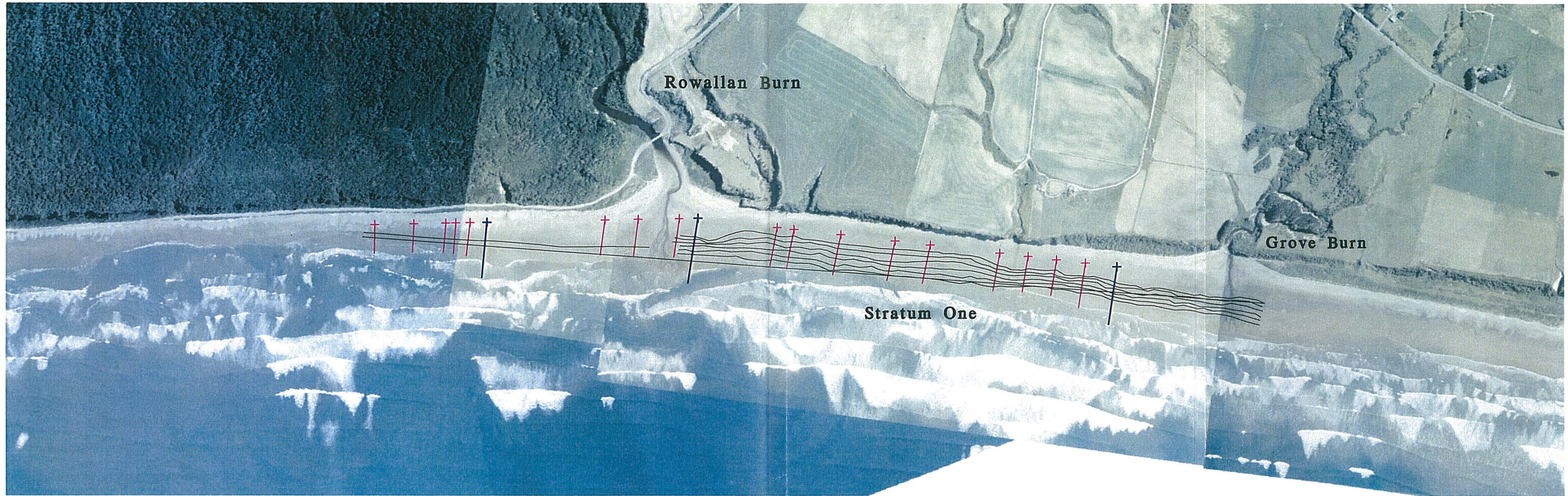
Figure 4.3. Transects of the excavation survey and siphon activity counts within the Orepuki Beach survey area.



Joins Figure 4.4b
→

- Key:**
- Strata boundaries
 - Transect lines
 - Siphon counting transects

Figure 4.4a. Transects of the excavation survey and siphon activity counts within the north-western section of the Bluecliffs Beach survey area.



- Key:**
- Strata boundaries
 - Transect lines
 - Siphon counting transects

Figure 4.4b. Transects of the excavation survey and siphon activity counts within the south-eastern section of the Bluecliffs Beach survey area

4.3 Results

Density estimates generated for non-juvenile toheroa by the siphon activity counting technique yielded much lower density estimates than those of the average density from the excavated quadrats across the same area at all three sites (Table 4.1). Oreti Beach had the highest average non-juvenile toheroa density estimates from the excavation surveys. However, Oreti also had the lowest siphon activity densities which were conducted during the lowest average temperatures (Table 4.1). The siphon activity surveys were conducted over an average of moderately cool days but the range of weather conditions were not consistent across the three sites.

Table 4.1. Mean values with associated ranges for each variable across all beaches and for each beach individually. Brackets contain lower and upper ranges. QD = quadrat density for excavation surveys; SC = densities from siphon activity counts.

	All beaches	Oreti	Orepuki	Bluecliffs
QD (N^o/m²)	2.61 (0-18.6)	3.33 (0-18.6)	2.11 (0-12.0)	1.08 (0-13.0)
SC (N^o/m²)	0.20 (0-7.1)	0.01 (0-0.5)	0.44 (0-7.1)	0.19 (0-1.8)
Air temp (°C)	12.9 (9.1-18.6)	11.2 (9.5-12.4)	14.3 (12.0-18.1)	16.2 (14.1-18.6)
Sand temp (°C)	11.6 (9.1-13.1)	9.9 (9.1-11)	13.7 (13.1-16.1)	12.5 (12.1-13.1)
Wind speed (m^s)	1.5 (1.2-3.1)	1.5 (1.1-3.1)	1.6 (0.8-2.8)	1.0 (0.5-1.4)
Cloud cover (%)	52 (30-100)	69 (50-100)	39 (10-80)	27 (20-100)

Correlation between weather variables was expected, and confirmed (Table 4.1). Initial simplification of potential regression models involved the elimination of sand temperature due to its high inter-correlatedness with air temperature. This choice was partly motivated by pragmatic reasons and a goal to design a monitoring protocol for the community to use. Measuring air temperature requires less specialised equipment than for sand or water temperature. Also using air temperature eliminates the possible influence of the tide on the sand temperature.

Table 4.2. Correlation matrix of the measured predictive variables. Values show Pearson's correlation coefficient with associated *p*-values. QD = quadrat density for excavation surveys; SC = densities from siphon activity counts.

	Beach	SC (N°/m ²)	Air temp (°C)	Sand temp (°C)	Wind speed (m ^s)	Cloud cover (%)
QD (N°/m ²)	-0.248 <i>p</i> < 0.001	-0.092 <i>p</i> = 0.143				
SC (N°/m ²)	0.173 <i>p</i> = 0.006					
Air temp (°C)	0.772 <i>p</i> < 0.001	0.056 <i>p</i> = 0.378				
Sand temp (°C)	0.707 <i>p</i> < 0.001	0.185 <i>p</i> = 0.003	0.828 <i>p</i> < 0.001			
Wind speed (m ^s)	-0.163 <i>p</i> = 0.010	-1.35 <i>p</i> = 0.032	-0.483 <i>p</i> < 0.001	-2.07 <i>p</i> = 0.001		
Cloud cover (%)	-0.633 <i>p</i> < 0.001	-0.058 <i>p</i> = 0.358	-0.824 <i>p</i> = 0.000	-0.711 <i>p</i> < 0.001	0.509 <i>p</i> = 0.000	
Tide direction	0.054 <i>p</i> = 0.396	0.118 <i>p</i> = 0.061	-0.094 <i>p</i> = 0.134	-0.183 <i>p</i> = 0.003	-0.093 <i>p</i> = 0.139	0.035 <i>P</i> = 0.577

4.3.1 Predictive power of siphon activity counts

A total of 253 comparisons of siphon activity counts for each horizontal transect with absolute abundance estimates from quadrats (vertical transects) were included in the original modelling (Oreti = 121; Orepuki = 94; Bluecliffs = 29; Fig. 4.2a-4.4b). The normal quadrat density (QD) versus log₁₀ siphon activity count density (SC) displayed higher *r*² values than log₁₀QD vs log₁₀SC (Appendix 1). However, in order to meet the assumptions of linear regression more comprehensively both the quadrat and siphon activity count densities were log₁₀ transformed. All cases with either zero quadrat or zero siphon activity counts were eliminated from this model, reducing the total sample size to 124 (Oreti = 58; Orepuki = 58; Bluecliffs = 8).

4.3.1.1 Justification of beach variables included in model

The remaining Bluecliffs Beach comparisons were removed from the model due to the limited sample size creating confounding results. Upon removing the Bluecliffs beach data the unexplained variance within the model reduced by 1.8%. However, even with the elimination of the Bluecliffs Beach data, the effect of beach on the predictive power of siphon activity counts was repetitively significant (Appendix 1). Both the quadrat density and siphon activity density are closely correlated with beach representing the variation in average density of non-juveniles across the three colonies (Table 4.1).

Unfortunately beach was also highly correlated with the weather variables, suggesting that across the varying density there was not enough variation in the weather conditions at each beach. Siphon activity at Oreti Beach was measured in much cooler average conditions and across a narrower temperature range (i.e. 3 °C range) than was experienced at Orepuki Beach (6 °C). An unbalanced design was created in which the Oreti Beach data had poor predictive power given the relatively limited range of weather conditions experienced when the siphon activity was observed. Therefore it was reasoned the most reliable model to describe the relationship between the two monitoring methods could be constructed from the Orepuki Beach data alone.

4.3.1.2 Justification for predictive variables included in model

Further systematic exploration of the Orepuki Beach model was therefore investigated using a back stepwise approach to investigate the influence of each remaining predictive variable. Tide direction was a redundant predictor in all previous models (Appendix 1) and was therefore justifiably eliminated first from further models. The removal of cloud cover improved the fit of the data and fractionally improved the model fit (Table 4.3). Air temperature and cloud cover were highly inter-correlated and cloud cover and wind speed were also inter-correlated to a lesser extent but the relationship was still significant (Table 4.2).

4.3.1.3 Orepuki Beach correlation results

The raw data from the two monitoring methods at Orepuki Beach present no significant correlation in general (Table 4.2; Fig. 4.5).

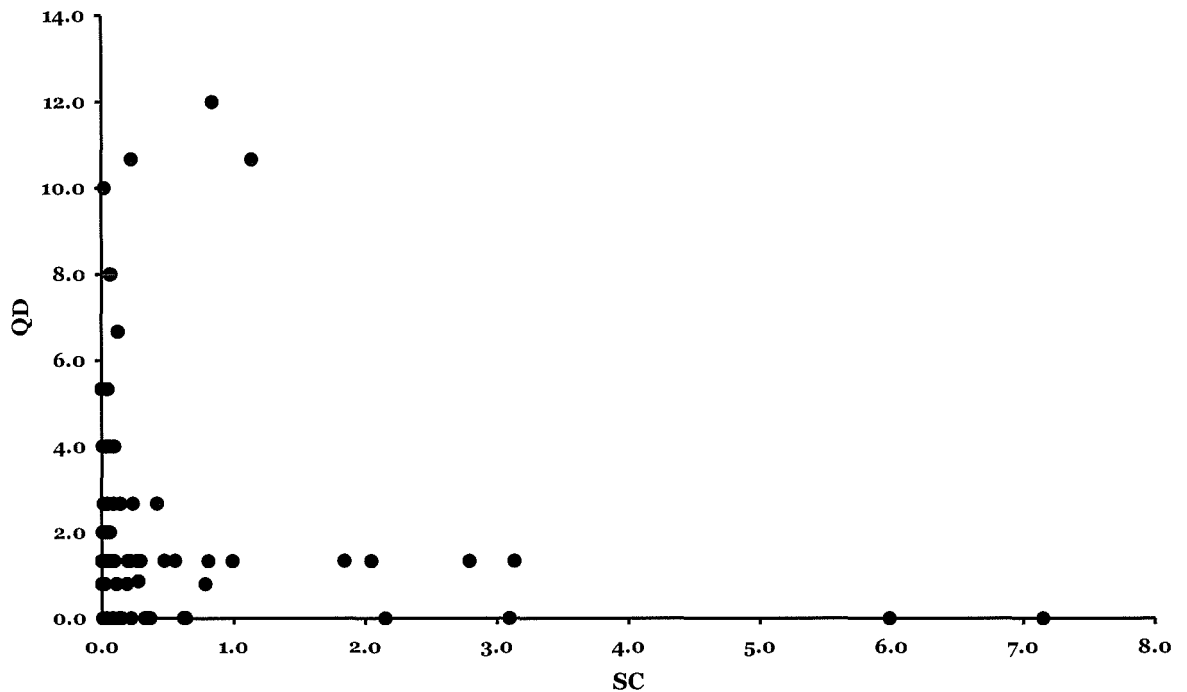


Figure 4.5. Non-juvenile toheroa density estimates from siphon activity surveys (SC) against the density estimates of excavation surveys (QD).

The best model to describe the relationship between quadrat density and siphon activity count for the Orepuki Beach data is described by the following equation:

$$\text{Log}_{10} \text{excavation quadrat density} = -1.26 + 0.080 \text{ Log}_{10} \text{ siphon activity count density} + 0.087 \text{ Air temperature} + 0.269 \text{ Wind speed}$$

All three predictor variables included are positively related to the quadrat density. Air temperature and wind speed both significantly contribute to the quality of the model (Table 4.3). The overall model presents that a least one of the variables included is having a significant effect. However, the model has little overall predictive power ($R^2 = 12.1\%$; Fig.4.6). Changes in air temperature and wind speed created very little variation in the quadrat densities predicted across increases in siphon activity densities (Fig. 4.6).

Table 4.3. Results of backwards stepwise exploration of the Orepuki Log_{10}QD vs Log_{10}SC model. QD = excavation quadrat density, SC = siphon activity counting density. The red outlined area represents the output from the best fitted regression model.

Orepuki Log_{10}QD vs Log_{10}SC					
	Combination of predictive variables				
	Air+Wind+ Cloud+Tide	Air+Wind +Cloud	Air+Wind	Air+Cloud	Air
<i>n</i>	58	58	58	58	58
Constant*	0.013	0.014	0.014	0.256	0.857
<i>log₁₀SC*</i>	0.170	0.264	0.270	0.575	0.487
Air temp*	0.004	0.004	0.003	0.089	0.218
Wind speed*	0.006	0.008	0.005	*	*
Cloud cover*	0.293	0.346	*	0.226	*
Tide direction*	0.327	*	*	*	*
R²(adj)	12.0%	12.0%	12.1%	1.1%	12.1%
ANOVA^μ	0.039	0.029	0.019	0.314	0.354
N° of unusual cases	2	3	3	3	4

* Regressional coefficient

^μ p-value

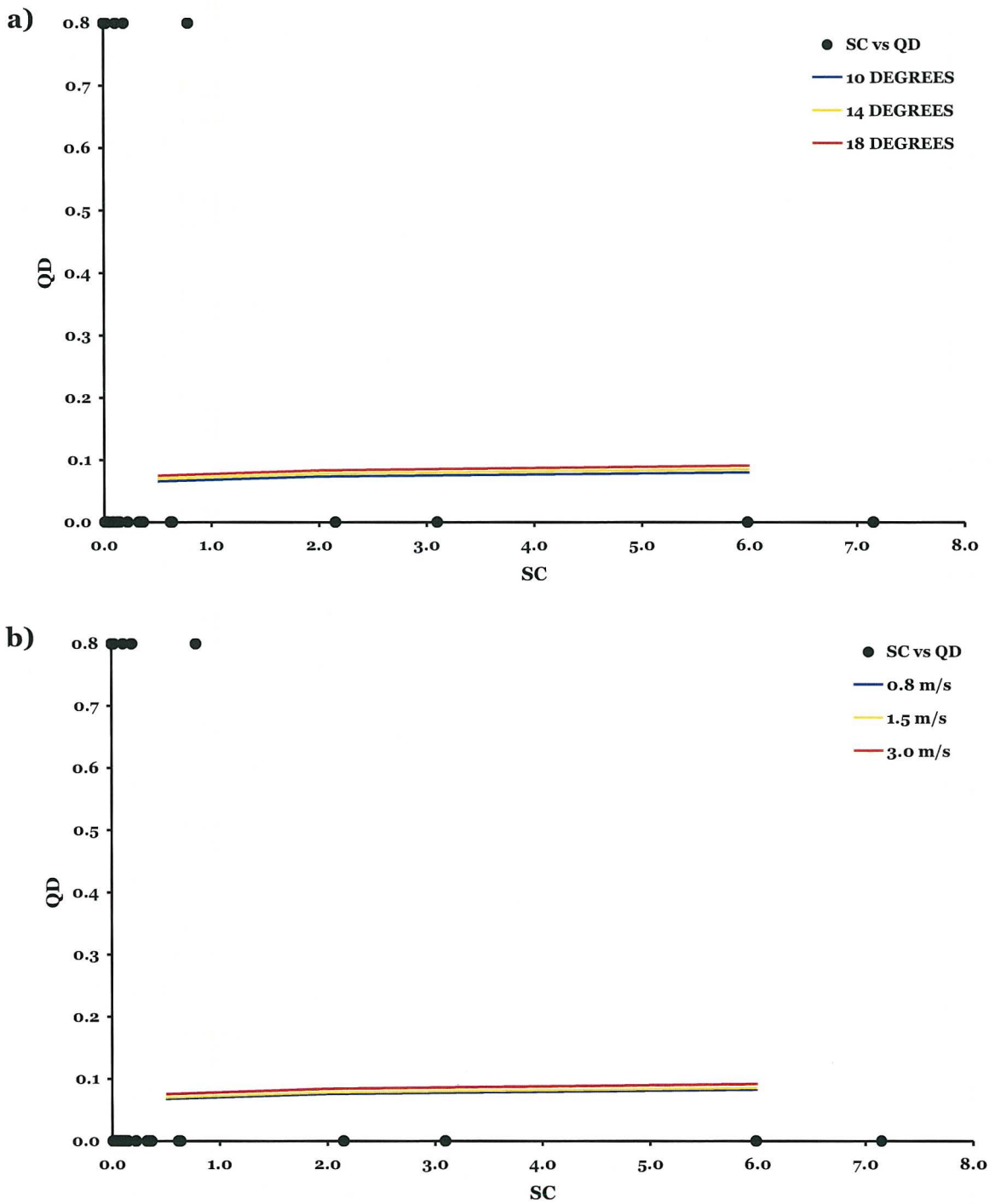


Figure 4.6. Best fit model of the Orepuke data across a range of a) air temperatures; and b) wind speeds. Black circles represent the non-juvenile density estimates of the siphon activity counting method (SC) against the quadrat excavation method (QD). Note the finer scale on the QD axis in order to comprehend the predicted density estimates.

4.3.2 Detecting toheroa presence

All siphon activity counts with a density greater than zero were included in investigating the detection probability of toheroa. All three beaches were included in this analysis to ensure the maximum variation in air temperature (i.e 9.1-18.6 °C). Wind speed was removed in order to simplify the model as it was not a significant contributor in the previous analysis for two out of the three beaches.

From the raw data, a detection rate of 64% (124/193 cases) was observed with no regard to the air temperature. The best fitted logistic regression equation to predict the probability of detection from air temperature is given by:

$$Y_{(\text{probability of detecting siphon activity})} = -3.776 + 0.357\text{Air temperature}$$

The coefficients for both the constant and air temperature have a significance level of less than 0.05 providing sufficient evidence that they are not zero and are important contributors to the logistic regression model (Table 4.4). Similarly the G-statistic indicates air temperature as a predictor (G-Stat₁, *p*-value <0.05). As air temperature increased the proportion of cases that detected siphon activity increased. The odds of detecting toheroa increase by a factor of 1.43 (95% CI 1.20 - 1.71) for each unit increase in the log air temperature. However, the confidence intervals for the proportion of cases detecting toheroa at each temperature are wide (Fig. 4.7). The Hosmer and Lemeshow goodness-of-fit test showed the fitted multiple logistic regression model predicts the data moderately well ($\chi^2_{(6)} = 7.86$, *p*-value = 0.249) (Fig. 4.7). However the confidence intervals are wide reducing the applicability of the model (Fig. 4.7).

Table 4.4. Output from logistic regression modelling the relationship between air temperature and detectability of toheroa via siphon activity searching.

Predictor	Coef	SE Coef	Z	P	Odds Ratio (95% CI)
Constant	-3.776	1.093	-3.46	0.001	
Air temp (°C)	0.357	0.090	3.94	0.000	1.43 (1.20 - 1.71)

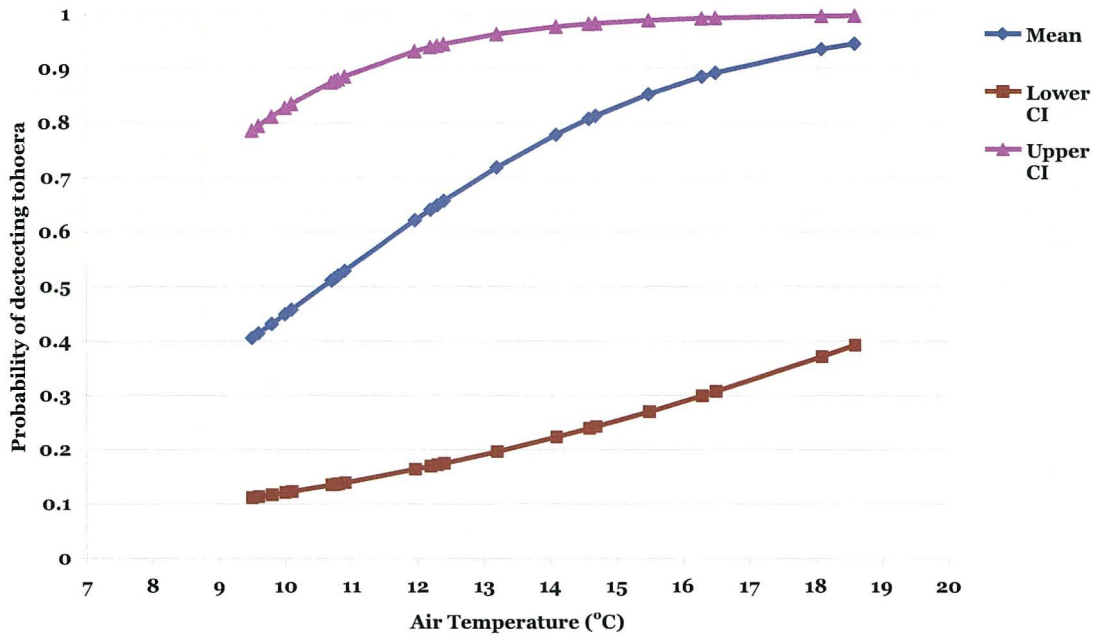


Figure 4.7. Logistic regression fitted model of the probability of detecting a toheroa with the siphon activity search technique across a range of air temperatures (with 95% confidence intervals). Note x axis does not start at 0°C.

Given the significant influence of air temperature on the probability of detecting toheroa, the air temperature at which the siphon activity searching technique is best suited needed to be determined. From predicting the detection probability of observing one toheroa if they are present in the area from the model, the accumulative probability of detecting them over successive re-visits to the sites is shown in Figure 4.8. As temperature increases the probability of detection increases therefore the fewer visits searching for siphon activity are required to determine toheroa presence or absence. If the air temperature is above 14 °C a site would only need to be visited twice to be 95% confident toheroa would be observed if present and only once if the air temperature is above 16 °C (Fig. 4.8).

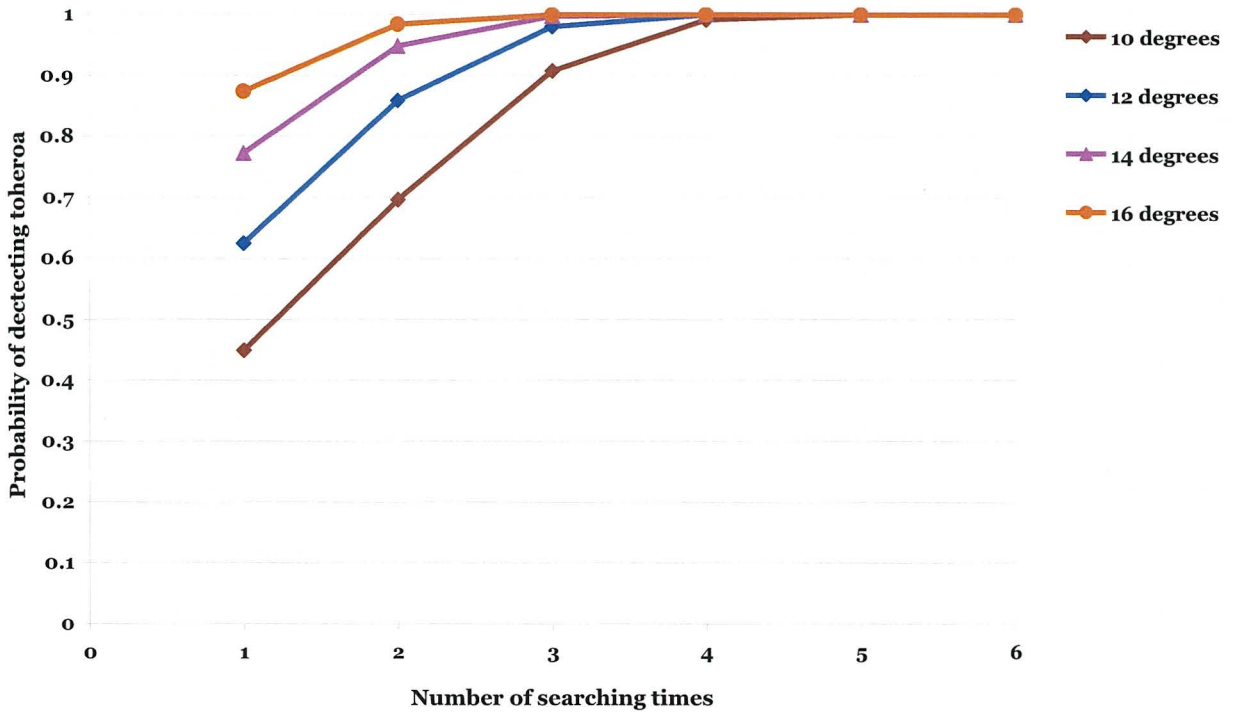


Figure 4.8. Accumulative probability of detecting toheroa with the siphon activity search technique if they are present for an array of air temperatures.

4.4 Discussion

4.4.1 Predictive power of siphon activity counts

Non-invasive abundance indices are being developed in order to replace destructive survey techniques, such as hydraulic dredging and grabs and excavations. These techniques can cause high levels of disturbance and potential damaged to the study species and the surrounding benthic communities (e.g. Nobbs & McGuinness 1999; Watling *et al.* 2001). Although excavation surveys are thought to be more precise, abundance indices are believed to be superior given their lower costs and minimal disruption to the benthic systems (Jordoa & Oliveira 2003). The development of monitoring regimes that local communities can conduct themselves is also desirable in collaborative partnerships to facilitate participation.

The abundance index based on the traditional search method of observing siphon activity proved to have very poor ability to predict toheroa density and abundance (i.e. $R^2 = 12.1\%$). The inclusion of the most important contributing predictor

variables generated relative density estimates that are a poor indicator of actual toheroa abundance. This substantially low predictive power suggests there is an unmeasured variable or a range of variables that is/are substantially influencing the relationship between the density estimates of the two monitoring methods. Additional caution is advised when considering the ability of the siphon activity counting technique to predict absolute abundance due to the degree of inter-correlation between the predictors.

Excluding the beach variable from the combined modelled data of Oreti and Orepuki beaches presented an even poorer relationship. This suggests that the proportion of toheroa active is a result from the effect of both beach site and the weather variables together. The significant variation between the sites (i.e. significant influence of beach) meant no generalisation could be inferred about the predictive power of the traditional monitoring based technique across the three study sites. The very low distribution and density of toheroa at Bluecliffs Beach meant there was relatively less opportunity to calibrate siphon activity counting for this site. The elimination of the data from both Oreti Beach and Bluecliffs Beach critically reduced sample sizes and the range of the predictor variables available for modelling. However, siphon activity counts at Orepuki were conducted across a considerably higher variation in weather conditions than Oreti thus presenting greater variation in which to explore the predictive power of the traditionally based monitoring tool. For each beach certain weather conditions may influence the proportion of toheroa that are active (i.e. have siphons extended).

The best model for predicting the relationship between siphon activity count density and quadrat density for the Orepuki data expresses wind as a significant predictor variable whereas wind shows no importance in the Oreti or Bluecliffs models. Therefore the importance of wind speed in the Orepuki model could either be that siphon counting in the densest area of the colony occurred during windy weather or the strength of the wind influences the proportion of active toheroa at Orepuki Beach. Including a wider range for each weather condition at all three beaches would help in determining what influences the behaviour of the toheroa. If this can be understood, a more robust model for the predictive ability of the traditionally based index could be developed. If the model cannot be generalised across the beaches, the application of the relative density index at potential future sites of toheroa colonisation would not

be appropriate. The new model would have to be developed for each beach if these discrepancies in response to the different weather variables are not overcome.

Differences in the observer's counting may have introduced further discrepancies within the results. Standardisation of the observer's speed and searching area was completed. However, reaction times to the visual stimulus may have varied. The number of toheroa that are not being observed in the siphon activity searches due to the disturbance by the surveyors and the visual indicator disappearing before the observer detects it is assumed to be a constant proportion at each beach. Other factors not included in the model that may answer for the large variation in the density estimates between the two systems include: 1) changes in activity due to availability of food sources; 2) time spent actively feeding during the last tidal cycle; 3) moon phase; and 4) reproductive season (Joardao & Oliveira 2003). Flores *et al.* (2005) suggests that different size classes may follow different feeding patterns which would introduce another level of variation. Furthermore Bradbury *et al.* (2000) found a relationship between season and the proportion of geoduck clams actively extending their siphons at a given time. Thus the accuracy of the correlation may be influenced by the time of year or vary across several years.

The outlying cases in which considerably higher toheroa densities were recorded in the excavation surveys but corresponded with very low toheroa densities from the siphon activity counting surveys are of particular concern and mostly likely had large influences on the model. These inconsistencies may have resulted from toheroa redistributing within the survey area in the period of time between the completion of both survey techniques.

Through the comparison of the two methodologies, the applicability and limitations to the traditional monitoring technique can be identified. The most obvious limitation to the traditional monitoring techniques is the exclusion of the juvenile class. Toheroa populations are characterised by sporadic and variable recruitment, which is governed by processes that are poorly understood (Redfearn 1974). Thus the more toheroa recruitment rates are investigated the more informed future management will be. An equally important limitation is the lack of information concerning size or age structure, as there is no indication of the size class of the toheroa associated with the visible siphon tips/holes. As the siphon holes are not

permanent in the sand, the classification of the size judged by the size of the hole or distance between the siphon tips would be very subjective. At least two of the interviewees believed you could target the larger toheroa by eyeing up the size of the siphon tips. The siphon diameter of clams has previously been found to be related to clam size (e.g. Zwarts *et al.* 1994; Millar 2004). However as clams such as toheroa and tuatua retract their siphons when disturbed, accurately calibrated photographic/video equipment is required to measure the siphon diameters. The introduction of such methodologies would greatly increase the cost and skills required to utilise the siphon hole counting technique. Unfortunately these downfalls would render it unacceptable as a community-led monitoring approach. However, the potential for developing such a non-invasive technique for experts/scientists is valuable as including an assessment of size distributions means the abundance of the breeding stock or recruitment levels would be known.

4.4.2 Detecting toheroa presence

The amount of active toheroa may vary over time due to variations in the behaviour of individuals within the population (Salgado-Kent & McGuinness 2006). Therefore in order for the siphon activity searching to provide the best indication of toheroa presence/absence, observations need to be conducted in conditions when the toheroa are most active (i.e. the majority are carrying out feeding behaviours). Interviewee A was adamant weather conditions influence the proportion of toheroa active:

“Like I say with the weather - that’s they won’t show on the cold, wet sort of weather so you can get the same thing like you know nothing there and then the old cloud rolls away and the sun comes out and ‘zoomf’ they’re everywhere, little holes all over the beach” (Interviewee A).

Thorarinsdottir & Ragnarsson (2001) advised that in order to attain ‘peak values’ when measuring the abundance of the siphonate clam species quahogs (using photography of siphons), surveys need to be conducted in the summer months. Conducting surveys in summer allows for warmer temperatures and ample supply of food to ensure animals are actively feeding.

The siphon activity search technique for toheroa is most reliable when the air temperature is above 16 °C. An increase in temperature above 16 °C does not greatly

increase the probability of witnessing a toheroa on a first searching attempt thus sites should be visited twice in ≥ 16 °C. Searching for toheroa presence in these conditions will ensure that highest majority of toheroa are active therefore increasing the chance of interception by observers. Although not an accurate estimator of population density or abundance the siphon activity counting technique may provide detailed distribution data. Assessment of the distributions within toheroa beds via siphon activity surveys can help identify the boundaries of the colonies and aid in directing more effective two phase sampling procedures (e.g. Akroyd 2008; Morrison & Parkinson 2008). Siphon activity observations could also be used to assess whether or not populations have established from any future transplanting efforts. Assessing the presence of founding populations at new sites with the siphon activity searching technique will remove the need to conduct blind, invasive excavation surveys.

4.4.3 Conclusions

The inclusion of weather variables in the analysis did not help construct a valid relationship between siphon activity counts and actual toheroa density. In order to calibrate the traditionally based monitoring tool further predictor variables would need to be measured. Furthermore, a monitoring tool based on non-juvenile toheroa only is fairly coarse, would underestimate population abundance and provide no indication of recruitment levels. The current excavation surveys are crucial in determining the recruitment levels and age/size structure of the toheroa colonies. However, should a relationship between the two survey techniques be identified with further investigations the traditionally based monitoring tool could allow the kaitiaki to assess the toheroa stocks in the periods between the formal surveys. The applicability of using siphon activity searching to assess toheroa presence is promising and could potentially determine the distribution of the colony within sites. The probability of detecting toheroa can be increased by surveying in warmer conditions (i.e. higher air temperatures). To obtain a 95% confidence of detecting toheroa when actually present it is advised two surveys be conducted in the lower reaches of the intertidal zone when air temperatures are 16 °C or warmer.

CHAPTER FIVE

Beach traffic impact investigation

“I would say if I was in charge of the beach I wouldn’t have any traffic on it ever. If you are really worried I wouldn’t have any traffic to the east at all, particularly where that race was”

Interviewee W

5.1 Introduction

Sandy beaches are the most intensively exploited coastal system (Brown & McLachlan 2002). The nature and degree of the anthropogenic pressures on sandy beaches depends on the type, concentration and frequency of those activities pursued (Schlacher & Thompson 2007). Recreational activities associated with sandy shores include fishing and shellfish harvesting, walking, swimming, surfing, sun-bathing, kite/wind surfing, land yachting, camping, horse riding, mountain and motor biking and four-wheel driving (Priskin 2003a; Davenport & Davenport 2006).

There is growing international concern that vehicles may have significant adverse effects on sandy beach ecosystems. Four-wheel driving is the primary tourism-related concern for managing habitat degradation of the central coastal region of Western Australia (Priskin 2001). The impacts of vehicles on sandy beach environments include the erosion of sand from dune systems and damage to the vegetation (McAtee & Drawe 1980; Rickard *et al.* 1994; Groom *et al.* 2007). Negative impacts on sandy beach fauna have been reported in crabs (Wolcott & Wolcott 1984; Steiner & Leatherman 1981; Barros 2001; Moss & McPhee 2006; Foster-Smith *et al.* 2007; Schlacher *et al.* 2007b), clams (Hooker & Redfearn 1998; Van Der Merwe & Van Der Merwe 1991; Schlacher *et al.* 2008b), sand dollars (Brown & McLachlan 2002), turtles (Hoiser *et al.* 1981) and sandy shore associated birds (Watson *et al.* 1996; Williams *et al.* 2004). Additionally, lower densities, reduced distribution, small body sizes of macrofauna and reduced species richness have all been associated with highly urbanised beach areas (Barros 2001; Velsco *et al.* 2006; Velsco *et al.* 2008) and beach zones experiencing high intensity traffic (Stiener & Leatherman 1981; Moss & McPhee 2006; Foster-Smith *et al.* 2007; Schlacher *et al.* 2008a).

Vehicles can impact sandy beach fauna directly (i.e. crushing/burying of animals) or indirectly through habitat modification (i.e. loss of vegetation, sand displacement and changes to substrate properties) (Gilbertson 1981; Anders & Leatherman 1987). Vehicle traffic can increase the level of compaction and reduced the moisture, infiltration and organic carbon levels of the soil matrix, along with increasing the diurnal temperature range (Wilshire *et al.* 1978). The size class, speed, intensity and driving behaviour (straight versus swerving) of vehicles needs to be explored as these all may influence the intensity of beach traffic's impacts on macrofauna (Schlacher *et al.* 2008b).

Vehicle traffic on Aotearoa beaches has increased both in intensity and extent since the 1950s, however, there is a lack of reliable scientific investigation of its local effects. Toheroa, a highly prized, endemic, infaunal surf clam of Aotearoa has variable and poorly understood recruitment rates which increases the risk of stock failure. Beach traffic has been recognised as a potential threat to toheroa populations (Hooker & Redfearn 1998; Gray 2004) and understanding the intensity of this threat will help guide suitable management regimes. Oreti Beach, Murihiku sustains the largest toheroa population and is also a popular beach for recreation. The average number of visitors at Oreti Beach per day between 16th December 1998 and 10th February 1999 was 961, with approximately 374 vehicle visits per day (Wilson 1999⁵). Gray (2004) found significant overlap between the distribution of both toheroa and beach traffic at Oreti Beach. However, overlap does not imply the toheroa are being damaged by the beach traffic, but does indicate the potential for such impact to occur (Schlacher & Thompson 2007).

Motorcycle beach racing is a particular traditional recreational activity that has regularly occurred on Oreti Beach since the 1920s (*David Morris, President of Southland Motorcycle Club, pers. comm.*). In the last three years an annual beach motorbike race has been marketed as the 'Burt Munro Challenge', an important part of a three-day motorcycle racing festival. Participation in the festival is growing rapidly. The impact of the levelling of the race track before the event with a grader and the large number of motorbikes racing and the spectators cars on the beach are of concern to some interviewees (refer to Chapter 2), with most concerns surrounding

⁵ This was calculated by adjusting the estimated number of visitors by 94% (the estimated proportion that arrived by car – others walked, cycled or rode a horse) and dividing by the estimated average number of people in each car visit (calculated as 2.41 after weighting by weekend and week days from the data presented in Table 4.1 of Wilson 1999).

Chapter 5. Beach traffic impact investigation damage to the kōhanga sites. Investigation into the putative impacts of beach traffic on the toheroa colonies was desired:

“Oh yeah I think that would be a good idea. It’s always a simmering issue otherwise and it would put it to bed a wee bit you know where there’s damage and where there’s not damage” (Interviewee F).

Interviewee F particularly supported the need for formal scientific investigation as his concerns expressed about vehicle damage to the toheroa colonies have thus far been largely disregarded, for example:

“Back in the 90s when they were developing the regional coastal plan I was on about trying to restrict traffic on the beach, and they said “Oh, because of the toheroa, oh you’ve got no evidence, you can’t do it - Oreti Beach is a road under the City Council” and all these sort of things” .

The importance of Oreti Beach for both local recreation and the maintenance of a strong toheroa population may raise conflict concerning the use of the beach. It is therefore paramount that reliable scientific estimates of the impact of vehicle traffic on toheroa recruitment are made as a first step to considering mitigation options.

The specific aims of this preliminary investigation were to:

1. Investigate the risk posed to toheroa by the Burt Munro Challenge (BMC) beach race on Oreti Beach.
2. Measure the risk posed by different categories of vehicle on individual toheroa during normal public use of Oreti Beach.
3. Discuss potential ways that any risks found could be mitigated and identify priorities for follow-up research.

5.2 Methods

5.2.1 Burt Munro Challenge Beach Race

The BMC Beach Race took place at Oreti Beach on the evening of the 28th November 2008. A ‘before race’ (27th-28th November) and ‘after race’ (29th-30th November) survey design was constructed to assess the impact of the race on the toheroa beds

within the area. Customary Authorisation for this study was given by the Waihopai Rūnaka (N^o SI 01528).

The BMC beach race track was a half mile circuit which began 1.15 km south-east of the main entrance to Oreti Beach and extended a further 850 m south-east (Fig. 5.1). Public parking and pit areas were contained within the one kilometre zone from the entrance and public viewing stands and amenities were on the supra-littoral zone and dunes above the race track (Fig. 5.1). The initial race track was positioned with the mid-line approximately 5 m below the high water line. The circuit was predicted to be relocated downshore, in parallel, twice throughout the duration of the racing.

Official BMC beach race organisers provided guidance on the race track layout in order to design the before race survey for which an after race survey was to be duplicated in the same area to allow for direct comparisons. Unfortunately the true race track layout differed from the original design as: 1) the 'start line' was shifted approximately 120 m south-east; 2) the race track straight extended for 800 m instead of the 500 m advised; and 3) alternative to the entire race track being relocated downshore twice, the north-western end was reset once and the south-western end was retained in the same location but the turning circle boundaries were broadened (Fig. 5.2).

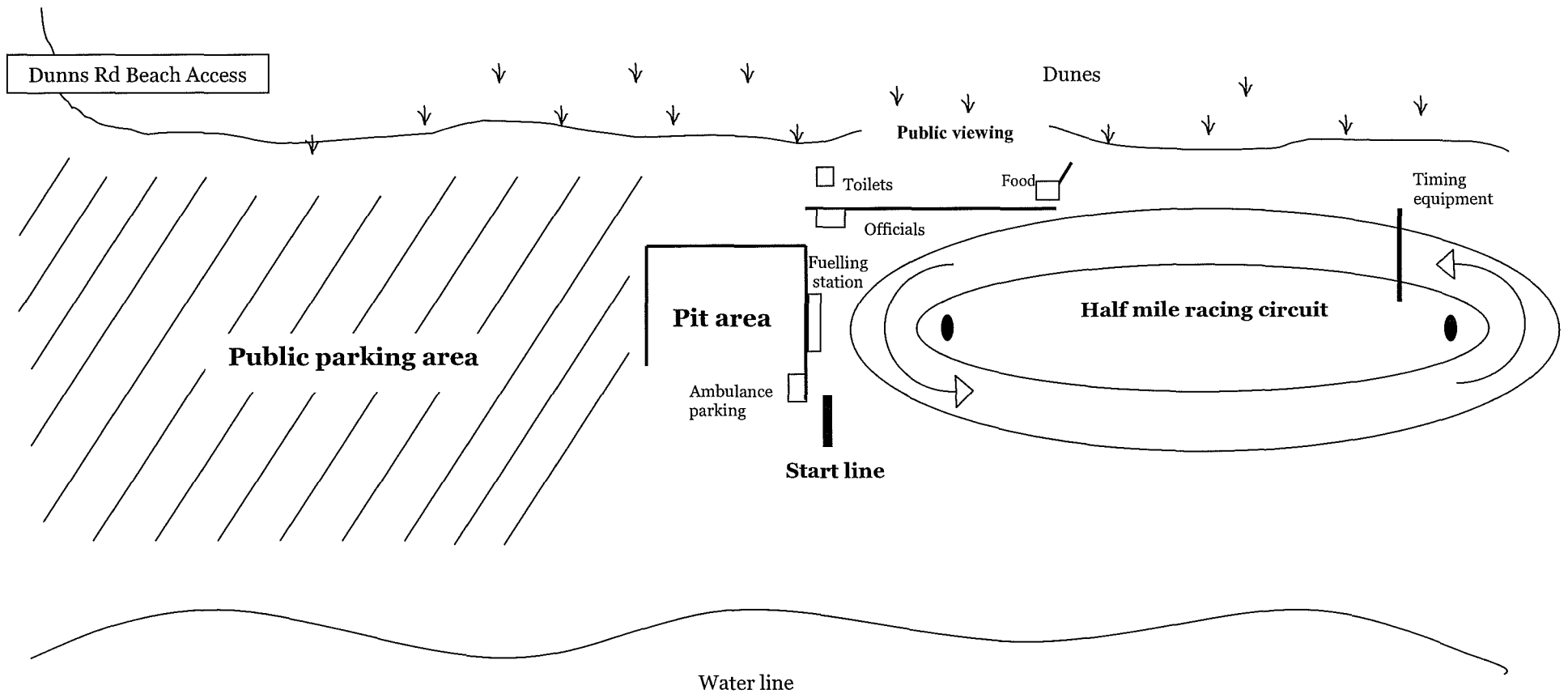


Figure 5.1. Layout of the Burt Munro Challenge beach race event. The public viewing and pit areas were sectioned off with wire fences. The timing equipment was dug under the surface of the track.

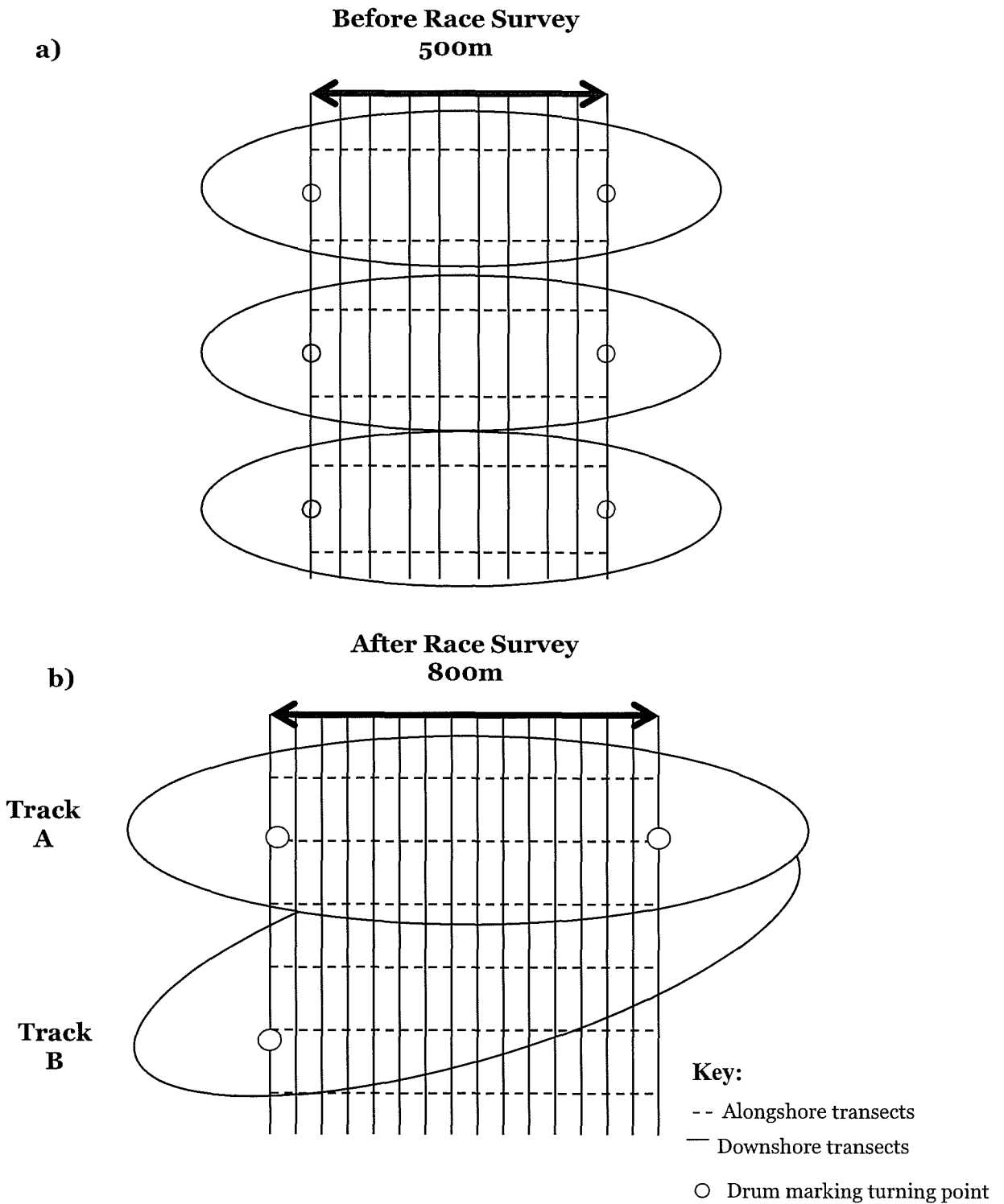


Figure 5.2. Survey design to measure abundance of toheroa a) before; and b) after the Burt Munro Challenge beach, Oreti Beach, 26th – 29th November 2008. Track A illustrates the initial race track and Track B represents the track after it was reset.

Excavation and wet sieving of 0.5 m² quadrats (see section 3.2.3 for method details; Fig. 3.2) was used in both the before and after race surveys to assess and compare the abundance, length frequency and condition of the toheroa (i.e. if the toheroa are damaged) within the race track area. Prior to excavation of the quadrats (in both the before race and after race surveys) surface scans of the beach were conducted within the survey area. Any whole or partial remains of toheroa found on the sand's surface during the scans were collected. Surveys recording the number, species and activity of birds present on the surrounding race track area were conducted at three stages during both the before and after race surveys. The number and type of vehicles parked on the beach during the event were recorded, as was the total number of laps of the race track completed by the motorbikes during the event.

The survey areas were stratified into 50 m alongshore strata (before race $n = 10$; after race $n = 16$; Fig. 5.2). Each stratum contained one randomly placed transect, running down the width of the intertidal zone, perpendicular to the mid-line of the race tracks. Six quadrats were excavated 10 m apart down each transect. All intact toheroa and complete half shells (i.e. one valve) sampled were counted and longest shell dimension along the anterior/posterior axis were measured with vernier callipers to the nearest 1 mm. Any immeasurable shell fragments recognisable as toheroa were also recorded. To assess the condition of the sampled toheroa their shells were inspected for damage (i.e. cracks or chips) and those that presented no visible fatal damage were returned to the substrate and scored for motility. If the toheroa successfully dug and buried themselves in the sand they were classed as viable, if no effort to burrow was observed within 20 minutes of being returned to the sand they were classified as dead. In the after race survey, shell fragments that had the remains of flesh attached were also classified as dead individuals.

The last minute alterations to the race track's layout weakened the analysis of the originally planned before versus after race survey design. Concerns that biases would be introduced in the comparisons of the two survey areas were raised given the naturally variable distribution of the toheroa beds. The data was therefore analysed using two complementary methods:

- 1) comparisons across the subsection of the survey areas that overlapped (c.a. 400 m).

- 2) comparisons across the entire sampling lengths of both the before race (500 m) and after race (800 m) survey areas.

The second method relies on the assumption that there was equivalent overall density within the after race survey area as that of the before race survey area. For each method the density of a) alive and intact toheroa; b) dead/damaged toheroa; and c) toheroa shell fragments sampled in the before race and after race surveys were compared.

The sparse and patchy distribution typical of toheroa meant that many of the quadrats sampled contained no toheroa whereas some were observed to have up to seven. The skewed distribution of counts is not readily amenable to parametric statistical analysis, even after severe transformation of the data (Fletcher *et al.* 2005). Therefore the density of the before and after the beach race categories (alive, damaged/dead and shell fragments) were compared using 'bootstrapping' techniques (Manly 2007; Chernick 2008) by computing 10,000 random draws from the observed distributions, with replacement.

5.2.2 Vehicle passage

To assess the impacts of beach traffic on the toheroa at Oreti Beach four classes of vehicles were used, including: a car (Vehicle A), two different models of utility vehicles (Vehicle B & C) and an off-road motorbike (Vehicle D) (Fig. 5.3; Table 5.1). The vehicle passage investigations were conducted during the 9th – 12th of April 2009.

The smaller toheroa were considered the most vulnerable of the size classes to everyday beach traffic. This present investigation therefore focused on assessing damage to juvenile toheroa (≤ 39 mm) across a range of shore heights. Juvenile toheroa are inconspicuous when beneath the sand's surface. In order to expose juvenile toheroa to vehicle passes, individuals were collected while drifting on the sand surface of an incoming tide and experimentally translocated to marked positions. The downshore beach was divided into two zones, high (the top 10 m of the beach from the toe of the dunes) and mid/low (the remaining intertidal zone). Collected specimens were experimentally placed into alongshore transects within in each zone (high = 8; mid/low = 32). Transects contained 2-10 toheroa spaced 20 cm apart. The unbalanced design was the result of: a) some toheroa not successfully re-

establishing themselves; and b) refining the single direct passage over all toheroa in each transect by the test vehicles. Only translocated toheroa that successfully buried into the sand within 20 minutes were included in the vehicle passage investigation.

Table 5.1. Vehicle and tyre specifications of the four test vehicles used in the vehicle passage investigation on Oreti Beach, April 2009.

Test vehicle ID	A	B	C	D
Category	Car	Utility	Utility	Motorbike
Make/ Model/ Year	Toyota Fielder 2002	Mazda BT50 Freestyle Cab 2009	Isuzu Bighorn (1st Generation) 1990	Honda CRF 250R 2008
Weight* (kg)	1130	1876	1678	111
Pressure[¥] (kg/cm²)	1.30	1.34	1.31	0.28
Tyre Make/ Model	Goodyear Radial 185/70R14	Sumitomo Serengeti SL80	A/T GT Radial	Pirelli Scorpion (medium soft)
Tread depth (mm)	8	15	8	11
Width between lugs[†] (mm)	4-5	12-22	5-12	12-20

* Weights quoted are 'kerb weights', calculated as un-laden vehicle with oil and water coolants added and the fuel tank full.

¥ Pressure was calculated as kerb weight + 75 kg per driver + estimate of weight of gear being carried and divided by the area of tyre in contact with the ground when vehicle is parked on a hard surface. Front and rear tyres on motorbikes are slightly different, thus the average area was used assuming the weight of the vehicle and rider were distributed equally over both tyres.

† 'Lugs' are the raised segments of the tyre that are separated by treads.

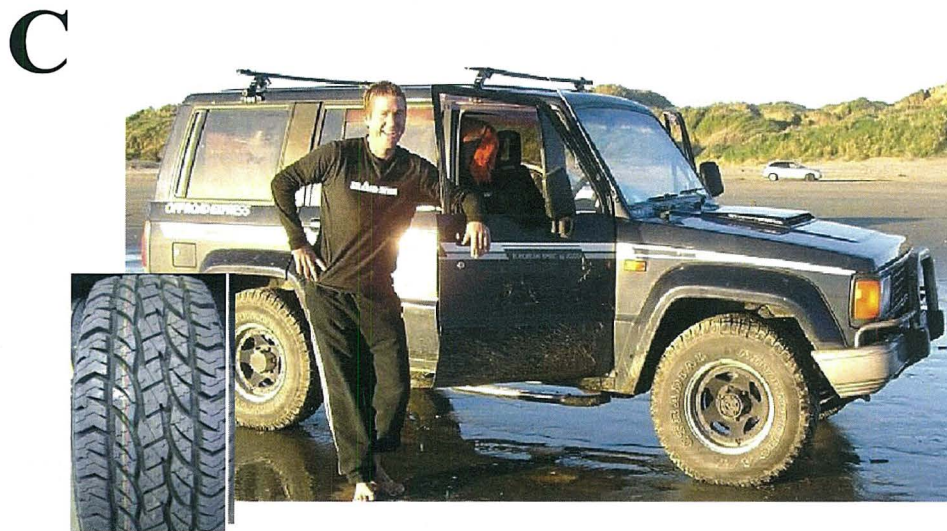


Figure 5.3. The four test vehicles used to investigate impact of vehicle passage on experimentally translocated juvenile (≤ 39 mm) toheroa. Insert shows close up of each vehicles respective tyre tread.

A total of 303 experimentally placed juvenile toheroa were exposed to the direct passage of the four test vehicles (Table 5.2). Vehicles were driven over the aligned toheroa once, at approximately 30 km per hour (the speed limit on Oreti Beach). In order to investigate the influence of repeated vehicle passage an additional five transects ($n = 50$ toheroa) were conducted in which five passes were made over each individual in Vehicle B, the heaviest of the test vehicles.

Toheroa exposed to the different test vehicles were carefully retrieved by wet sieving. Each toheroa was then measured and their condition assessed, firstly for any visible damage and later checked for viability using a motility score (refer to section 5.2.2). To control for the influence of the translocation and excavation during the retrieval of the test individuals a subsequent 170 drifting juveniles were collected and translocated to 1 m² of exposed saturated sand. Within a 20 minute release period 133 toheroa successfully buried themselves. Both the test and control individuals that failed to burrow into the sand were retained and trialled again in the motility scoring to confirm their non-viable status.

Table 5.2. Number of transects exposed to passage by test vehicles in the high and mid/low beach zones of Oreti Beach, and the number of damaged and undamaged juvenile (≤ 39 mm) toheroa recovered in April 2009.

Test vehicle	High beach zone			Mid/low beach zone		
	Transects	Damaged*	Un-damaged	Transects	Damaged*	Un-damaged
A	5	4	30	10	3	41
B	2	2	17	5	1	37
B _(5 passes)	1	3	6	5	2	37
C	-	-	-	6	0	61
D	-	-	-	6	11	48
Total	8	9	53	32	17	224

*The data in the table excludes four toheroa that were damaged during their excavation after the vehicle pass.

Comparisons were made across the proportions of viable test animals from 1) those that failed to completely bury themselves in the sand within 20 minutes; 2) the control group that successfully buried themselves and then were excavated; 3) those that were exposed to direct vehicle passage and were visibly undamaged; and 4) those that were exposed to direct vehicle passage and sustained visible damage. Fisher's Exact Tests were conducted using GenStat™ (Edition 9) to test the null hypotheses of equal risk across the different models of vehicles and strata due to low overall proportions of damaged toheroa. Distributions of the length frequency of toheroa were markedly skewed, therefore non-parametric tests to compare median sizes of experimental/control and damaged/undamaged groups were used.

Soil penetrometer readings (the force required to drive the penetrometer 8 cm into the sand) were taken to measure the compaction of the sand surrounding the test individuals ($n = 20$ readings per transect) prior to the vehicle passing. A further 25 downshore transects (300 m apart) were constructed with readings taken at: 1) the base of the sand dune; 2) in any vehicle track between the dune and the high water mark and 3) at 25 pace intervals down the beach from the high tide mark to the low tide mark. For each downshore transect the sand was graded as percentage wetness at ten downshore heights between high and low water. The degree to which the penetrometer readings could predict damage rates of toheroa was investigated using a multiple logistic regression model on all data except the motorbike (Test Vehicle D) trials.

5.3 Results

5.3.1 Burt Munro Challenge Beach Race

5.3.1.1 Race track and traffic intensity

The race track area was calculated at a conservative measure of 6.37 ha (850 x 75 m). The majority of the motorbikes kept close to the mid-line of the track however some veered downshore into the saturated sand (75-100 m below the mid-line of the track) after coming out of north-western turning circle (Figure 5.4a). The turning circles received the highest degree of rutting (Fig. 5.4b).

a)



b)



Figure 5.4. Burt Munro Challenge beach race a) straights; b) turning circles, 28th November 2008, Oreti Beach.

Ticket sales suggest that around 6,000 spectators, along with 150 competitors and approximately 20 organisers attended the BMC Beach Race event (*David Morris President of the Southland Motorcycle Club, pers. comm.*; Fig. 5.5). Including practice runs and occasional race restarts, a total of 88 laps by racing quad bikes and a further 3040 laps by a range of two-wheeled bikes were completed on the half mile race track (Table 5.3). With all bike classes combined, a minimum of 5161 km was travelled during the racing event, 67% of which occurred on Track B (see Fig. 5.2.b). Traffic in the track area by organisers prior to and during the event is not included in the data presented in Table 5.3. Racing quad bikes reached an average speed of 150 km/hr along the straights with the fastest being approximately 180 km/hr. The two-wheeled bike's speeds averaged around 180 km/hr and reaching tops speeds of 200 km/hr (*David Morris, President of the Southland Motorcycle Club, pers. comm.*).

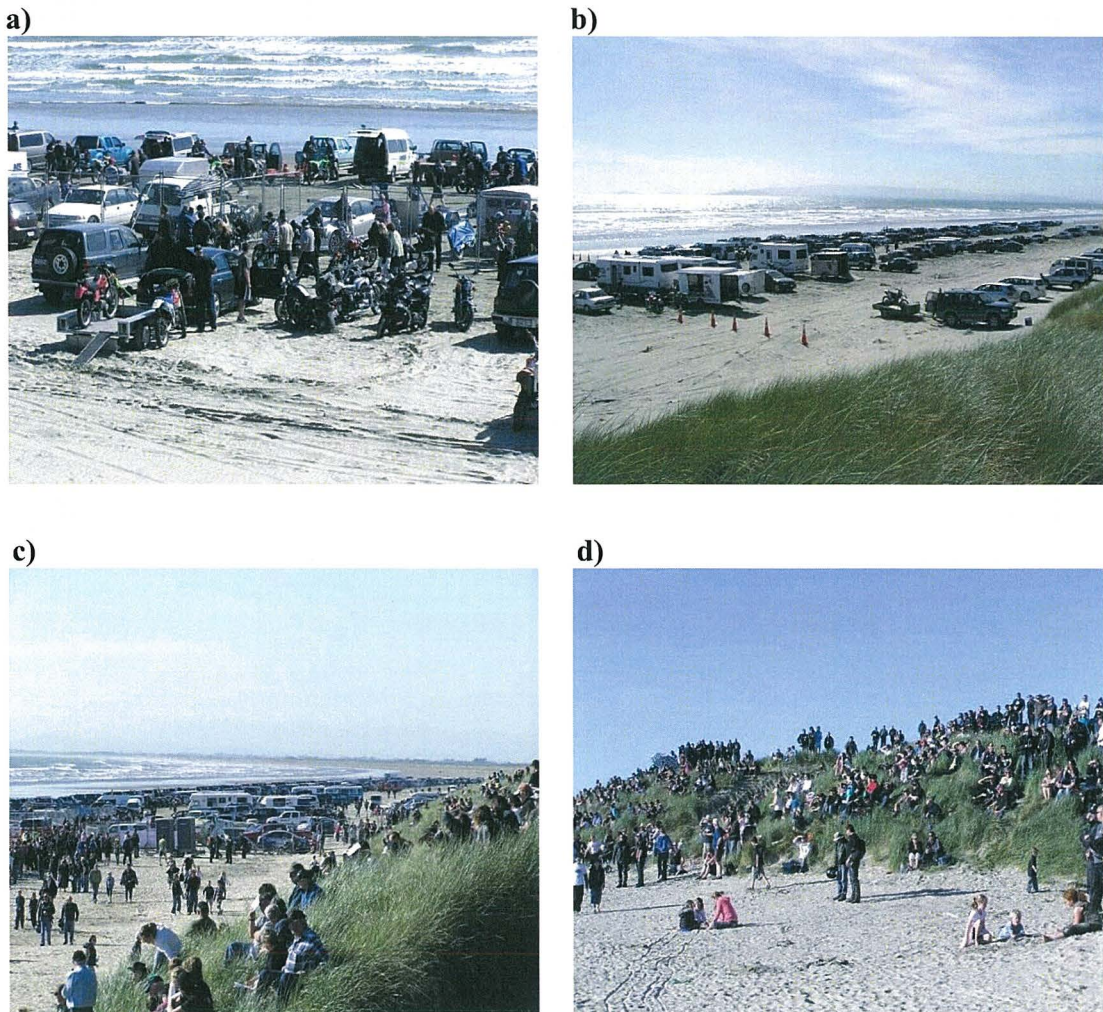


Figure 5.5. Vehicles, spectators and competitors at the Burt Munro Challenge beach race, 28th November 2008, Oreti Beach.

A total of 108 ha of the intertidal zone was covered by the racing bikes (Table 5.3). Assuming the bikes evenly distributed their pressure over the full extent of the race track area (6.73 ha) it was calculated that each point of the course received 16 repeated passes by the bikes. However, the inside zones of the turning circles and those areas along the mid-line of the course received proportionately higher levels of race bike passage than those on the outer edges of the turning circles and the straights.

Approximately 1734 vehicles were counted in the area of beach allotted as a ‘carpark’ (Table 5.4). These vehicles contributed to an additional traffic pressure in the order of 17, 000 km (i.e. each vehicle within the car park travelled an average of 500 m to their park and then 500 m to leave the beach).

Table 5.3. Traffic intensity of racing motorbikes on the Burt Munro Challenge beach race track, 28th November 2008.

	Motorbike class	N ^o of participants	Laps per race	Total passes*	Distance [‡] (km)	Area covered [†] (ha)
Track A	Quad	11	3-5	88	145	10
	Two-wheeled	213	2-8	883	1457	29
Track B	Quad	0	NA	0	0	0
	Two-wheeled	236	3-37	2157	3559	70
Track A+B	Quad	11	3-5	88	145	10
	Two-wheeled	449	2-37	3040	5016	98
Total		460	2-37	3128	5161	108

* Total passes are the total laps made by all participants combined.

‡ Cumulative distance travelled by a vehicle (number of passes x 1650 m per pass)

† Total area covered by a tyre, calculated as the distance covered multiplied by the number of wheels per vehicle x average width of each tyre (98 mm for motorbikes, 175 mm for quad bikes).

Table 5.4. Number of vehicles parked on Oreti Beach for the Burt Munro Challenge beach race, 28th November 2008.

Vehicle type	Number
Cars	755
SUVs/Utilities	392
Vans & people-carriers	104
Campervans	7
Small trucks	10
Non-racing bikes	19
Buses (2 running continuously)	10 [†]
Trailers	37
Total	1734

† Estimate of the number of round trips made by buses.

5.3.1.2 Before versus after race survey results

Due to the late finish of the BMC on the evening of the 28th November 2008, the track/survey area was exposed to one high tide event overnight prior to the after race survey being conducted. Furthermore quadrats in the lower shore levels of the north-western strata were exposed to a second high tide before the completion of the survey. Very few birds were recorded in the vicinity of the race track during the before ($n = 4$) and after ($n = 13$) race surveys (Table 5.5). All individuals surveyed appeared to be roosting rather than actively feeding during the survey periods. No exposed or damaged toheroa were found on the sand surface prior to the before race survey, however, a total of 48 definite toheroa remains, including 31 intact dislodged animals were found after the race.

Table 5.5. Bird scan counts during before and after race surveys.

	Total bird scan counts	
	Before race	After race
Black-backed gull (<i>Larus dominicanus</i>)	2	4
Red-billed gull (<i>Larus novaehollandiae</i>)	2	7
Oystercatcher (<i>Haematopus ostralegus</i>)	0	2

A total of 22 intact toheroa were sampled in the 60 quadrats of the before race survey. A further three were classified as damaged or dead. The damage observed was assumed to be inflicted by the spades during excavation of the quadrats therefore these specimens were classified as alive prior to the race event. From the 96 excavated quadrats of the after survey 35 viable and 39 damaged/dead toheroa were sampled. Forty-seven intact half toheroa shells were recorded in both the before and after race surveys. Remnant toheroa shell halves were found in the same density in both the before and after race surveys whereas toheroa shell fragments were found at average densities of 1.1 m⁻² and 2.7 m⁻² respectively for the before and after race excavation surveys.

The number of viable toheroa decreased when considering both the 400 m overlap area and the entire tracks from the before and after race survey, whereas the number

of dead/damage and toheroa shell fragments increased (Table 5.6). However, the certainty of these average estimates is marred by considerably large confidence intervals. The mean density ratio of the alive, damaged/dead and shell fragments of toheroa compared before and after the beach race illustrated the same trends (Table 5.7). The number of individuals classified as alive after the event compared to before suggests that around 56% of the toheroa were killed in the overlapping zone and around 71% were killed across when the full track areas are considered (Table 5.7). The density of damaged/dead and toheroa shell fragments increased in the vicinity of 5.3-6.0 times and 2.6-2.9 times respectively.

Table 5.6. Estimated density (number per m²) of alive, damaged/dead and fragments of toheroa on Oreti Beach before and after the Burt Munro Challenge beach race, 28th November 2008. Brackets show 95% confidence intervals generated from the 2.5th and 97.5th percentiles of the bootstrapping (10,000 simulations with replacement).

Area	Alive		Damaged/Dead		Fragments	
	Before	After	Before	After	Before	After
400 m overlap zone	1.17 (0.70-1.67)	0.32 (0.13-0.55)	0.13 (0.03-0.27)	0.81 (0.42-1.35)	1.13 (0.67-1.67)	3.32 (2.39-4.32)
Total length of race track	1.50 (1.03-2.00)	0.65 (0.39-0.92)	0.14 (0.03-0.28)	0.74 (0.48-1.06)	1.08 (0.67-1.53)	2.72 (2.03-3.47)

Table 5.7. Estimated mean ratio of the number of alive, damaged/dead and shell fragments per m² before versus after the Burt Munro Challenge beach race on Oreti Beach on 28th November 2008. Brackets show 95% confidence intervals generated from the 2.5th and 97.5th percentiles of the bootstrapping (10,000 simulations with replacement).

	Alive	Damaged/Dead	Fragments
400 m overlap zone	0.29 (0.10 - 0.59)	6.05 (2.26 - 26.13)	2.93 (1.77 - 5.37)
Total length of race track	0.44 (0.25 - 0.72)	5.29 (2.34 - 22.15)	2.62 (1.59 - 4.22)

The intensity of damage to the toheroa within the race track area was interpreted from the reduction of alive/undamaged animals sampled in the after race survey compared to the before race survey (i.e. the total number killed is the product of the decrease in alive toheroa density, the initial (before race survey) alive toheroa density and the area of the race track area). This equates to around 50,000 (95% CI 20,000-70,000) toheroa (Table 5.8). When considering the abundance of damaged/dead individual toheroa in the track area after the race, a generally lower estimation of impact is calculated (Table 5.8). A proportion of the damaged/dead toheroa sampled in the after race survey may have resulted from mechanical damage from the spade during the excavation of the survey plots. Thus to the value of 11.1% (3/27 damaged rate from spades in before race survey) was used to correct for this (Table 5.8). These estimations may still be inflated due to toheroa being crushed by the race bikes into large pieces leading to one dead animal being counting multiple times during the survey. The reduction in abundance of alive toheroa between the two surveys is therefore considered the most reliable estimate of the number of toheroa killed during the race. Following the predictions of the 400 m overlap (the most accurate method of comparison), the BMC beach race caused a 72% (95% CI 40-90%) mortality of toheroa occupying the race track area.

The majority of toheroa sampled within the surveys were juveniles (≤ 39 mm) with a small proportion (6%) of sub-adults (40-99 mm) (Fig. 5.6). A high proportion of individuals between 11-30 mm were found damaged on the surface and damaged/dead and alive in the sand (Fig. 5.6).

Table 5.8. Estimated number of toheroa killed and the number of new toheroa shell fragments added to Oreti Beach by the Burt Munro Challenge race on 28th November 2008. Brackets show the equivalent of 95% confidence intervals generated from the 2.5th and 97.5th percentiles of the bootstrapping (10,000 simulations with replacement).

	Decrease in abundance of alive toheroa	Abundance of damaged/dead toheroa	Abundance of damaged/dead toheroa excluding spade damaged	Increase in fragments
400 m overlap zone	53,531 (20,085 – 89,661)	51,411 (26,734 – 86,371)	45,756 (23,793 – 76,870)	139,020 (71,014 – 210,237)
Total length of race track	54,417 (19,615 – 89,904)	46,859 (30,512 – 67,564)	41,705 (27,156 – 60,132)	104,071 (51,899 – 157,195)

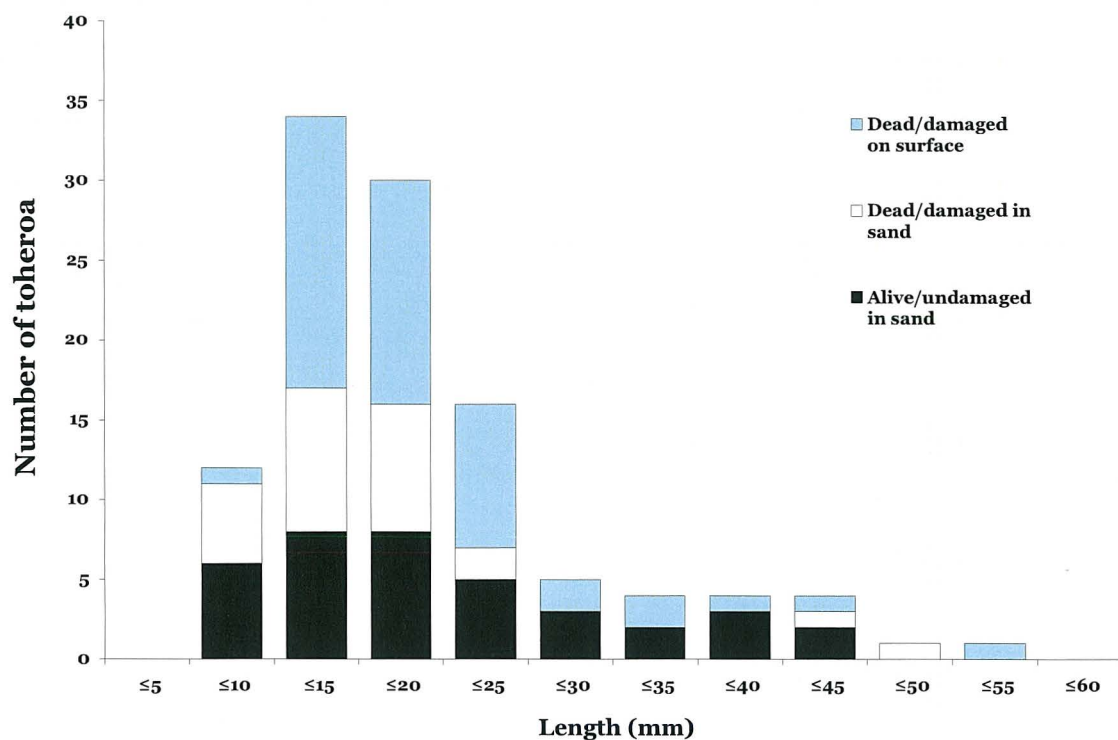


Figure 5.6. Size frequency distribution of toheroa found alive, dead or damaged on the surface of the racetrack or within the sand after the Burt Munro Challenge beach race, 28th November 2008.

5.3.2 Vehicle passage

5.3.2.1 Impact of test vehicles on toheroa

On inspecting the condition of the test animals after exposure to the traffic treatment, common damage to the toheroa were chips to the leading edge of the shells and fractures across one of the two valves (Fig. 5.7).



Figure 5.7. Examples of damage to experimentally placed toheroa after exposure to passage by test vehicles, Oreti Beach, April 2009.

Vehicle D, the motorbike, presented the largest threat to the juvenile toheroa beds, damaging 18% of test animals in the mid/low shore transects compared to an average of only 3% damaged across the other test vehicles. After one pass Vehicle A and B showed fairly similar levels of impact on toheroa experimentally placed in the high shore zone. When exposed to five repeated passes by Vehicle B however, damage rates in the high shore area increased substantially although not statistically (single pass ($n = 19$) or five repetitive passes ($n = 9$), Fisher's Exact test, $p=0.29$; Fig. 5.8a). In the mid/low shore transects no distinct differences between Vehicle A & B's impact rates were recorded (Fig. 5.8b). Test Vehicle C showed no impact on the toheroa exposed to its passage (Fig. 5.8). As the motorbike (Vehicle D) and one of the utilities (Vehicle C) were not tested on the high shore area, they were excluded from the overall comparison of levels observed combined over the high and mid/low zone. Only 3% of toheroa were damaged in the mid/low shore area compared to 14% in the high shore zone (Fig. 5.8).

Of the 33 juveniles from the control sample that did not successfully re-establish themselves in the sand only one (3%) showed signs of being viable in the motility testing three days later. In contrast, 29% of those that dug initially were able to dig in the laboratory three days later. Slightly more (35%) of the apparently intact sample that had been run over by our vehicles dug into the laboratory sand tray three days later, but the difference between this ability amongst the undamaged experimental group and the control group was not statistically significant (Fisher's Exact Test, $p = 0.31$). However only 12% of those showing visible damage to their shells from having been run over were capable of digging in the motility test three days later – they were obviously dying at a faster rate than undamaged ones in laboratory conditions (Fisher's Exact Test, $p = 0.015$).

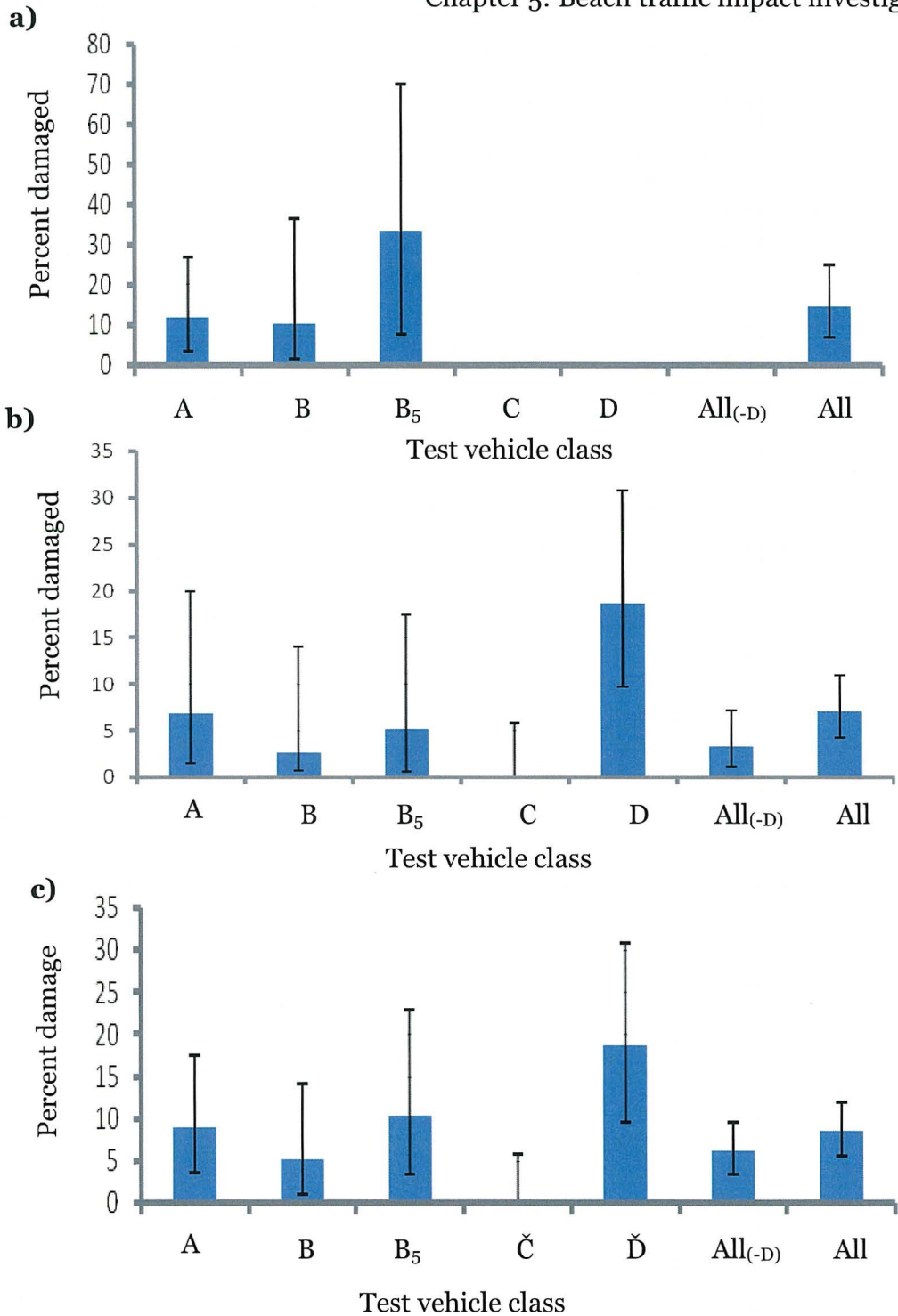


Figure 5.8. Percentage of experimentally placed toheroa that were visibly damaged by vehicles in the a) high beach zone; b) mid/low beach zone; and c) all parts of the beach combined. The error bar shows the 95% binomial confidence interval. Č and Ď represents the vehicle's data from the mid/low zone only. Note the different scale on the y axis of 'a'.

5.3.2.2 Size frequency

The toheroa used in the beach traffic impact study were all juveniles (≤ 39 mm) and presented a skewed length distribution with a strong mode of specimens between 9–13 mm (Fig. 5.9). These animals represent a slightly biased sub-sample of animals drifting on the surface of the rising tide. To ensure the widest range of size classes were tested, larger juveniles (>20 mm) were targeted. However, there was no evidence to suggest that those larger juveniles were more capable of burying themselves in the sand given the average size of toheroa that successfully buried themselves was 11.7 mm (95% CI 11.1–12.3 mm) compared to 12.0 mm (95% CI 11.1–13.0 mm) for those that failed. Furthermore, there was no significant difference found between the length of those damaged and undamaged within the test individuals exposed to a single vehicle passage (Mann-Whitney U Test, $p = 0.28$).

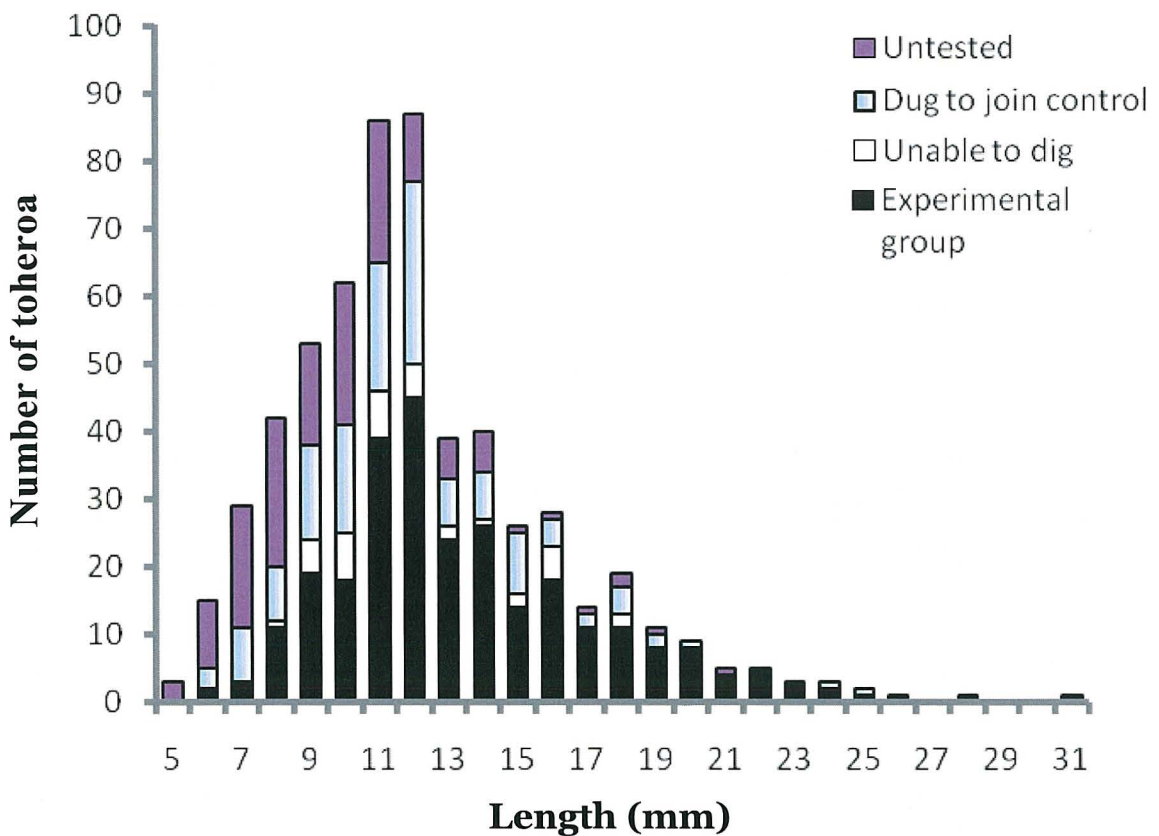


Figure 5.9. Length frequencies of gathered juvenile toheroa for vehicle passage investigation.

5.3.2.3 Penetrometer readings

The sand was relatively penetrable close to the dunes and on the lower half of the beach where it is visibly wet or covered in shallow standing water at low tide (Fig. 5.10). The average penetrometer reading taken in the vicinity of each transect five minutes before the trial took place was not a significant predictor of the proportion of toheroa damaged ($p=0.18$). The instrument may not have been sensitive enough to detect a real effect, but more likely, the support of the embedded toheroa in very wet sand is probably relate to the incompressibility of water and consequent even support of the shell. We predict that degree of consolidation of the sand, and hence its penetrability, is likely to affect risk to toheroa only in relatively dry sand.

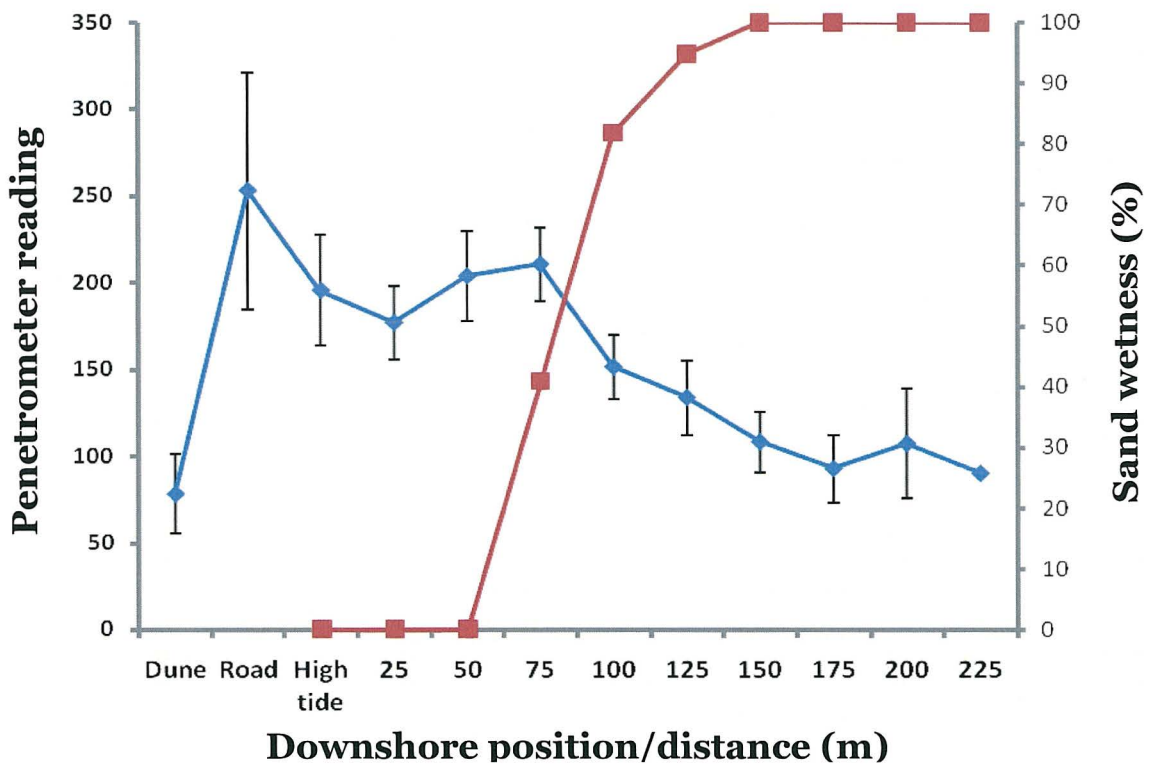


Figure 5.10. Sand compaction and wetness at different distances down Oreti Beach at low tide on 14th April 2009. The average penetrometer reading (blue diamonds) are shown for the base of the sand dune, a vehicle track ('road') was present above the high tide mark, at the high tide line and then at successive 25 pace intervals down the beach. The error bars are 95% confidence intervals. The level of sand wetness (red squares) refers to when the sand had a dark surface sheen or is covered by shallow pools of standing water.

5.4 Discussion

5.4.1 Burt Munro Challenge Beach Race

The BMC beach race is a significant vehicle event overlapping the distribution of the toheroa beds on Oreti Beach. Off-road motorbikes have been identified as having significant impacts on dune systems (e.g. Kutiel *et al.* 2000). However, the impact of beach racing on intertidal ecosystems has not been well documented. Estimates of the number and proportion of toheroa killed by the BMC beach race were broadly similar irrespective of whether the comparison of the before and after race survey was made across the entire length of the survey areas or only the 400 m overlapping area. Restricting the comparison to the 400 m overlap zone is probably the most rigorous approach as it avoids the assumption of equal density of live toheroa within the two designated areas prior to the beach race event. When considering only the restricted overlapping area of the before and after race surveys a mortality rate of 72% (40-90%) was observed and an estimated 53,000 toheroa were killed, the majority of which were juveniles.

This interpretation of the mortality rate is consistent with the increases in the number of the: a) damaged/dead toheroa on the beach surface from the scans; b) dead/damaged specimens remaining in the sand; and c) shell fragments buried in the sand. When drawing on the results of the vehicle passage study, single passes from a motorbike damaged 18% of the test juvenile toheroa - posing the highest risk to toheroa out of the four test vehicles.

The additional impact of vehicles on the beach associated with the race was not quantified. However, the findings of the vehicle passage investigation suggest the effect of cars parking on the beach may be detrimental to the toheroa beds. Furthermore, this traffic was funnelled into a u-shaped 'road' to direct the traffic in a clockwise direction into the car parking area and out the entrance again, such aggregated vehicle passages is known to increase the risk to infaunal invertebrates (e.g. van der Merwe & van der Merwe 1991).

The BMC beach race is a considerable threat to the recruitment success of toheroa along a 1-2 km stretch of Oreti Beach. The intensity of the impact of the racing event is probably a conservative estimate as: 1) the tides may have removed dead/damaged specimens from the race track area or introduced new viable uninjured individuals

into the area via drifting prior to the after race survey being completed; 2) apparently viable individuals may have died during the time after the race event due to internal injuries (an increased mortality rate in laboratory conditions over three days was witnessed in toheroa exposed to traffic passage than those not); 3) some animals killed during the beach race may have been damaged beyond what was recognisable as a whole animal and therefore not included in the count; 4) conservative dimensions of the race track area were used (i.e. the impact of the bikes travelling below the 75 m boundary was not assessed); and 5) the damage from the traffic within the 1 km car parking area was not assessed.

To put the impact of the BMC beach race (i.e. a 72% mortality rate) into perspective of the total Oreti Beach toheroa population, several factors need to be considered. The toheroa colony at Oreti Beach extends for 17 km (Beentjes & Gilbert 2006b) whereas the beach race event (including race track, car park and amenities) only occupied 2 km (5%) of the toheroa colony's area across the high to mid levels of the shore. Averaged over the entire Oreti Beach shoreline, 55% of juvenile toheroa occur in the top 100 m of the beach, 14% of sub-adults and 2% of the adults (as taken from Fig. 6 of Beentjes & Gilbert 2006b). Thus the race track is positioned high enough up the beach to avoid putting the adults and sub-adults at risk; even in the area immediately adjacent to the race track. The 53,000 juveniles potentially killed within the race track area was only 0.07% of the total 2005 estimated Oreti Beach juvenile population (Beentjes & Gilbert 2006b). Juvenile toheroa have a naturally high mortality rate (Redfearn 1974) therefore many of fatalities from the BMC beach race may have been lost to the population through natural causes. Finally as the BMC occurred prior to the main toheroa spawning season, there is the possibility that the race track area will be repopulated with either new recruits from spat settling in the area or through the migration of juveniles from the surrounding areas.

To reduce the overall impact of the BMC beach race on the local toheroa population effective protocols could be developed by the event organisers with the support of Environment Southland, the kaitiaki of Waihopai Rūnaka and researchers. In preparation for the 2008 BMC beach race event no sand levelling machinery (i.e. grader, levelling harrows, blades etc.) was used to smooth the race track prior to racing, unlike previous years. Very little can be done to mitigate the impact on the toheroa occupying race track aside from advising that the use of levelling machinery

be eliminated. Careful placement of the race track could minimise toheroa mortality. Interviewee W stressed that:

“Having the race in the middle [of Oreti Beach] is crazy – I understand the importance of the beach race to the people of Invercargill but there are other places [on Oreti Beach] they could have it. If I was in charge of the beach I wouldn’t have any traffic on it ever. If you are really worried I wouldn’t have any traffic to the east at all, particularly where that race was in 2008. They should be racing to the west of the Dunns Rd entrance. I wouldn’t allow any traffic any further than 2 kilometres to the east of the entrance, to protect the main eastern bed”.

The location of the 2008 race track occupied a relatively dense zone of juvenile beds surveyed in 2005 (as taken off Fig. 4 of Beentjes & Gilbert 2006b). Consultation with NIWA scientists who conduct the periodic toheroa surveys could help identify areas on Oreti Beach where toheroa exist in low densities (e.g. directly north-west of the Dunns Road entrance). The number of juvenile recruits being exposed to the race event could be achieved by positioning the race track as high on the shore as possible and holding the event as early in spring as practical.

The car parking area should also be carefully managed to reduce the impact of vehicles outside of the race track. Possible management strategies may include: 1) keeping all traffic above the high water mark; 2) ensuring traffic is travelling the least distance from the beach entrance; and 3) banning non-race vehicles from the beach. A walking track could be constructed through the dunes or alternatively a free bus could be used to drop spectators off within a walkable distance of the race track.

5.4.2 Vehicle passage

Within Murihiku, sandy beaches are designated as roads allowing any vehicle under 3.5 tonne to legally utilise the shore area (Southland Coastal Plan; Environment Southland 2008). With no marked driving zones/lanes the full extent of toheroa beds at Bluecliffs, Orepuki and Oreti beaches are exposed to detrimental impacts from vehicles. The results of this study suggest that every-day traffic on Oreti Beach is having an adverse impact on the juvenile toheroa population. The single passage of one four-wheeled vehicle or of a two-wheeled motorbike can inflict lethal damage to a juvenile toheroa buried in the sand (both instantaneously or increased mortality after

three days). These findings are consistent with Hooker & Redfearn (1998) who measured a 14% mortality rate in juvenile toheroa at Ninety Mile Beach (Taitokerau), although this was measured in higher than normal beach traffic conditions.

The level of damaged toheroa may have been underestimated if intact toheroa sustained internal injuries (i.e. injured but presented no signs of external damage). A possible bias in the number of toheroa damaged may have resulted from test animals being translocated to microclimates in the sand that they do not naturally inhabit, thus making them more susceptible to being damaged. Unfortunately due to the low sample sizes and the low percent damaged by the test vehicles the 95% binomial confidence intervals are relatively large, the true level of risk of each vehicle category is unclear. Further investigation is warranted and larger sample sizes are recommended (~400) for each vehicle treatment across the two shore zones. This study found no evidence to suggest repetitive vehicle passage had increased negative effect on toheroa, although further testing is strongly advised. Hooker & Redfearn (1998) conclude that multiple passes are positively related to increased damage in juvenile toheroa, and increasing their vulnerability to predation.

The risk of damage to beach clams from beach traffic is dependent on several factors including sediment properties, sensitivity of the animals, the depth at which they are buried, the models of vehicles and the quantity and distribution of the beach traffic (van der Merwe & van der Merwe 1991; Schlacher & Thompson 2007; Schlacher *et al.* 2008a). There was no evidence in either investigation to suggest that a particular length of toheroa within the juvenile size class (≤ 39 mm) was more vulnerable to vehicle damage. However, those individuals occupying the narrow zone at the high tide mark (10-15 m) appeared generally more susceptible to the adverse effects from beach traffic. In this zone the sand is softer, lateral movement of the toheroa is more likely and as juveniles only bury themselves a few centimetres below the surface (Kondo & Stace 1995) they are more exposed to potential crushing and suffocation. Cranfield *et al.* (2002) discussed beach traffic as a potential threat to the recruitment of tuatua (*P. donacina*) as the majority of the traffic drives along the upper zone which may alter the structure of the sand matrix at the high water mark. Similarly, van der Merwe & van der Merwe (1991) describe a greater disruption to the softer, drier sand of the high tidal zone due to the high degree of sand displacement and the nature of drivers to follow in others tracks. The juveniles lower on the beach appeared to be less vulnerable to damage from the passing vehicles. The compaction

of the sand however, was not observed as a good indicator of risk. The strong protection of even the small toheroa near the surface of the wet sand that prevails over most of the beach is the most likely explanation for generally low risk per vehicle pass. The mortality rates of a single pass of a car/utility vehicle and a motorbike of 3% (1-7%) and 18% (10-31%) are therefore believed to be the current best estimate of risk to juvenile toheroa.

The large toheroa which can burrow deeper in the sand at lower shore heights are presumed to be well protected against vehicle damage. Tyres on the moister sand of the lower shore appear to only disturb/displace the surface of the sand for several millimetres. The lower stretches of the beach are therefore relatively safe for adult toheroa because the area remains covered with water for a greater part of the tidal cycle, there are reduced shear forces and the rates of desiccation are decreased in exposed areas (Anders & Leatherman 1987; Wolcott & Wolcott 1984; Stephenson 1999). Larger toheroa also have the added protection of stronger, thicker shells. Previously, heavy vehicle traffic over the large toheroa beds has been voiced as a concern. The pressure of passing vehicles is believed to cause the valves of buried toheroa to close, expelling their interstitial water (Rapson 1952). With continual passes the sand will become thixotropic (less viscous) and the toheroa have been reported to 'float' to the surface making them vulnerable to crushing by vehicles or predation (Redfearn 1974; Hooker & Redfearn 1998). van der Merwe & van der Merwe (1991) reported a similar phenomenon in the successive passage of beach traffic over *Gastrosaccus psammodytes*. Future studies may wish to explore these phenomena, however, if no significant level of traffic is distributed in the lower beach zone then exposure to such repetitive vehicle passage is unlikely.

The larger and heavier utility vehicles appeared to pose very similar levels of risk to juvenile tohera as the test car, which is most likely due to pressure exerted by the utilities being proportionately reduced with larger and wider tyres. Tyres with wider deeper treads combined with high levels of torque are considered to pose the greatest risk to toheroa occupying the sand. Similarly, the driving nature of beach traffic has been proven to increase the risk to infaunal species and physical habitat disturbance. Schlacher *et al.* (2008b) found a rise in mortalities rate of clams from 1% to 53% when exposed to 40 swerving vehicle passes from 40 straight passes. The sand matrix was also observed to soften by a further 76% when the passes included turns.

Due to the sensitive nature of the back shore area and faunal communities related to the organic debris deposited within this zone, previous studies concerned with the management of beach traffic have generally advised vehicle passage to be limited to the intertidal zone below the high water mark (e.g. Atkinson & Clark 2003). However, with regard to toheroa, it would be advisable to keep traffic above high water for the most effective conflict management. Juvenile toheroa have the widest downshore distribution (Beentjes & Gilbert 2006a,b; Chapter 3) and thus keeping the traffic above the high water would restrict the overlap of toheroa and beach traffic to a minimum.

Although this present research demonstrates that vehicles damage juvenile toheroa, this is not tantamount to having demonstrated that vehicles in general significantly disrupt recruitment to the Oreti Beach toheroa population. Making recommendations for managing the year-round vehicle threat will be entirely premature until the overall risk is better quantified. A survey of the intensity and distribution (along- and downshore) of beach traffic at each of the three toheroa beaches would need to be conducted in order to develop an overall assessment of each vehicle categories' total risk to the toheroa populations in Murihiku. In order to develop the best management strategies to mitigate the risk of traffic to toheroa populations the degree of spatial overlap between vehicles and toheroa beds needs to be assessed. This assessment would need to detail the number and type of vehicles that are using which zones of the beach.

The present investigations clearly indicate that beach traffic in Murihiku is a threat to the toheroa. Further investigations need to be conducted to quantify this risk across larger sample sizes. Surveys on traffic intensity and distribution can then be applied to assess the overall threat of beach traffic to the three separate toheroa colonies and spatial areas. Finally, interviews with beach users would help define the nature of the seasonal use and the recreational value of carrying out their activities on the beach. This information would help direct the most effective management decisions.

Variations in recruitment rates of toheroa are not well understood but are most likely due to a combination of factors such as climate change impacts on sand and water conditions, human impacts and predation. If future investigations find that traffic is a significant contributor to toheroa recruitment failure, then coastal managers can begin to develop and implement intervention strategies to regulate beach traffic on

the sandy shores of Murihiku. The above factors all need to be considered and public education and awareness campaigns of the possible risks of beach traffic should be undertaken. Robust scientific evidence of the consequences of various management interventions will be needed to guide the debate and search for sustainable solutions.

CHAPTER SIX

General discussions

“Sometimes it is only through science that we can know that the things we are doing are wrong or even justify that we are right..... that we are doing okay in managing the resources”

Interviewee T

6.1 Population status and knowledge gaps

6.1.1 Population sizes

The Murihiku toheroa are of conservation concern as a result of their comparatively low abundance and the severe habitat degradation affecting the Bluecliffs Beach colony. Over the last decade of available monitoring surveys (1996-2005) the populations of both Oreti and Bluecliffs Beach appear relatively stable. However, when viewed in the historical context of prolonged decline and highly variable recruitment success there is obvious ongoing risk to the Murihiku toheroa meta-population. Historically, Oreti and Bluecliffs beaches both supported much larger toheroa colonies (Oreti = two million; Bluecliffs = 1-2 million; McKinnon & Olsen 1994). The population of legally sized toheroa (i.e. ≥ 75 mm) at Oreti Beach in 2005 (Beentjes & Gilbert 2006b) is only a quarter of its former size. Declines have been more intense at Bluecliffs Beach (8% of total former size), however this has been accelerated by the substantial habitat degradation. The alongshore range of the Bluecliffs colony is restricted to a section of beach less than half the length of the former range included in the original pre-1990s population surveys (Beentjes & Gilbert 2006b). The physical reduction of available suitable habitat for the toheroa colony at Bluecliffs Beach is the result of sand erosion (Beentjes et al. 2006).

The ultimate cause of the sand erosion is debated, but the majority of the local kaitiaki believe the diversion of water out of the Waiau River for the Manapouri power scheme since 1969 is the primary cause. This explanation seems plausible, as the scheme has significantly reduced the flow (by 75%) of the river and reduced the sediment load (Bradford-Grieve 1996 as referenced in Keeley et al. 2002). A review of the trends in the Bluecliffs Beach population shows declines were evident prior to the diversion of the river (Beentjes & Gilbert 2006a). However, this is too short a

period to be sure that declines were, or were not, occurring prior to the diversion of the Waiau River, particularly given the sporadic recruitment of toheroa colonies (Redfearn 1974). Furthermore, the Oreti Beach population has experienced substantial declines over the same period. It is unlikely the changes to the Waiau River are significantly affecting conditions for the Oreti colony situated 56 km away from the mouth of the river; thus it would appear some other ecological factor(s) are impacting the Murihiku toheroa populations.

Further understanding of the water current systems within the Te Waewae Bay area could help explain the process by which the sand from Bluecliffs has eroded (Beentjes et al. 2006). Habitat restoration is not a very practical option for a dynamic system such as the intertidal zone of Bluecliffs Beach. The identification of appropriate receiver sites for translocation efforts is highly recommended to create/establish more toheroa populations within the Murihiku area.

6.1.2 Meta-population age/size structure

The three Murihiku toheroa colonies present differences in their stock and size structures. The Oreti Beach population has a lower average density of non-juvenile (≤ 39 mm) toheroa than those of the Te Waewae Bay colonies. Broad scale juvenile recruitment occurs along the full extent (17 km) of Oreti Beach, whereas 80% of the breeding population occurs within a 1 km stretch of beach (Beentjes & Gilbert 2006b). This patchy recruitment success to maturity is of concern, and is poorly understood. Future investigations should attempt to understand what influences this spatial discrepancy, as the establishment of breeding colonies along the entire length of Oreti Beach would greatly increase the population's resilience. The stock structure of the Bluecliffs Beach toheroa population presents signs of recruitment failure (Table 3.2). The two most likely explanations for this deteriorated stock structure are: 1) the accumulation of gravels is preventing the successful settlement and development of juvenile toheroa (i.e. habitat degradation); or 2) reproductive success is being hindered due to critical reductions in the density of the breeding stock.

Through transplanting efforts of local kaitiaki a toheroa population has successfully established at Orepuki Beach, which is located at the opposite end of Te Waewae Bay from Bluecliffs Beach. The 'newly' established population supports a full range of cohorts. However, the stock appears to have reduced growth rates in comparison to the other two colonies. The presence of an established toheroa population at Orepuki

Beach represents the success of stock enhancement through translocation, but also a safe-guard for the Te Waewae Bay toheroa should the Bluecliffs population collapse. The inclusion of the Orepuki Beach toheroa colony in future periodic population surveys is advised. The results of the Orepuki Beach population survey presented in this study (Chapter 3) can be used as a baseline against which future studies can be compared, to determine the trend in population size and structure.

The variation in the stock structures and growth rates of the three colonies presents interesting questions about the differing habitat conditions between the beaches in which they occupy. Understanding optimal environmental conditions of a habitat and which factors have the largest influence on a population's health/status will be crucial in the identification of new receiver sites. Understanding and assessing such criteria about potential receiver sites will greatly improve the chances of successful establishment of founding populations. Newly established toheroa populations will only create a safe-guard population if they are successfully self-seeding. Meta-populations such of the Murihiku toheroa are maintained by the recruitment from source population(s), the loss of this/these populations will lead to the collapse of the colonies (Hanski 1999). The colonies of the three beaches, Oreti, Orepuki and Bluecliffs are managed as separated stocks, however, no genetic studies have been conducted to consider how interrelated the three colonies are.

6.1.3 Determining optimal harvesting size

The majority of previous toheroa research was conducted in the Taitokerau region in the 1950s-1970s, when toheroa were abundant and supported large commercial and recreational fisheries. In the recent past the prospect for toheroa research has been limited given the unstable state of populations, loss of commercial ventures and restricted opportunity for observation due to the prohibition of disturbance without authorisation (Keeley et al. 2002). It is unknown how applicable recorded biological parameters, such as growth rate and maximum age, are to the Murihiku toheroa stocks. The relevance of the minimum harvestable size limit (100 mm) implemented by the MFish for ensuring sustainable harvesting is also unknown for the Murihiku toheroa. A prominent traditional practice for the sustainability of wildfood populations is the protection of the breeding stocks (e.g. Futter & Moller 2009; Moller & Lyver in press). However, in order to implement effective size restrictions, the age/size classes with the highest reproductive potential need to be identified. Currently the age/size of toheroa with the highest reproductive output is unknown.

There is a potential that the minimal harvestable size (i.e. 100 mm) could seriously be influencing each colony's reproductive output. Investigation into the size at sexual maturity and modelling the reproductive output across a range of sizes would clearly indicate which size class is the most sustainable to harvest.

6.2 Threats

6.2.1 Beach traffic

The data indicates that beach traffic can cause mortality to juvenile toheroa in the intertidal zone in as little as one pass. The juveniles are vulnerable given their shallow position in the sand, particularly those occupying the soft band of sand at the high tide zone. The results of Chapter Five indicate that there is further need to investigate and quantify the total risk of beach traffic to each of the three Murihiku colonies. Stephenson (1999) warned that even if traffic only poses a mild threat it may be important to mitigate it as much as possible to ensure the maintenance of the remaining toheroa populations. The identification of beach traffic as a threat to the toheroa will unfortunately incur management conflict between allowing recreational access and also protecting the surf clam populations. Use of the beach is likely to increase in the future. Firm baseline measures of vehicle use could be matched with ongoing regular surveys of the toheroa populations to test putative impacts of people and their vehicles on this taonga species. Signage to inform and educate beach recreationists about the impact of traffic on the toheroa and how to minimise this threat could potentially reduce the risk. Mitigation efforts regarding the impact of the Burt Munro Challenge beach race include optimal placement of the race track and timing of the race, reducing the number of vehicles going onto the beach by managing spectator and competitor traffic and directing where the remaining vehicles drive once on the beach.

There will be much to gain from drawing key beach user groups into a working party from the outset. Each group can contribute detailed local knowledge in a search for practical solutions to moderating risk to the public, damage to the beach ecology and toheroa. User groups could include the Burt Munro Challenge organisers, Tangata Tiaki, MFish, Invercargill City Council, Environment Southland, Department of Conservation and researchers (e.g. NIWA, University of Otago, local experts). This community management group could also take a public lead to lobby and support more collaborative research to investigate why toheroa recruitment failure occurs in

many years on Oreti Beach. Implementing strategies for population restoration are required to build the resilience of the toheroa population to withstand enjoyable and important events, such as the Burt Munro Challenge beach race, year-round community recreation and sustained customary use of a taonga species for future generations.

6.2.2 Mass mortalities

Mass mortalities are common in many clam species; however, their increase in frequency and extent could pose significant threat to the Murihiku stocks. A mass mortality in early July 2009 at Orepuke Beach led to the death of approximately 0.9% of the total population. Analysis of deceased toheroa's flesh gave no indication of the cause of the die back (Larkin & Futter unpub. data). Understanding the cause of these events and recording their frequency and extent is important for sustainable management and in the development of mitigation measures if possible. The degree of environmental change to toheroa habitat induced by climate change should also be investigated as a possible risk factor.

6.2.3 Predation

Predation on toheroa is largely unmeasured and thus cannot be excluded as a significant threat to toheroa recruitment. Sea bird population surveys and toheroa consumption rates at each of the three colonies could be investigated to identify if bird predation is sustainable at the current harvest levels. Interviewee R alluded to the use of gull eggs in cooking in the past which consequently controlled the gull populations. If the removal of eggs from nests, in the vicinity of the toheroa colonies, is an ethical control option it may reduce predation pressure.

6.3 Harvest management and enhancement

6.3.1 Customary regulations

There was unanimous agreement that the customary regulations have delivered large cultural and environmental gains by instigating continuous wise customary management. Kaitiaki felt that the authorisation process allows more frequent harvesting opportunities (i.e. compared to previous open seasons), for those individuals who want the toheroa and will not waste it. More frequent harvesting gives rise to more opportunities to practise and pass down the tikanga and teachings regarding toheroa and wider mahinga kai philosophies.

Tangata Tiaki approach the authorisation of toheroa with caution; the right to harvest toheroa is a privilege and that needs to be respected. Although the populations appear stable, kaitiaki along with MFish should adopt the 'environmental precautionary principle' (Raffensperger & Tickner 1999). Especially considering the assumption that habitat degradation and further decline of the Bluecliffs Beach population will continue. A continued decline of the Bluecliffs colony forces greater emphasis on securing the Oreti Beach and newly discovered Orepuki Beach populations for continued customary use and ecological conservation.

6.3.2 Stock enhancement via translocation

To increase the overall resilience of the meta-population the use of the traditional enhancement tool of translocating animals could be applied to a) increase the density of existing toheroa colonies; and b) establish new populations within Murihiku. To prevent the local extinction of the Te Waewae Bay toheroa in the near future, efforts to accelerate the population growth of the Orepuki Beach population would be advisable. Enhancement attempts to extend the northern boundary of the Orepuki colony towards Gemstone Beach is a viable option, increasing numbers and reproductive potential of the colony.

Within the current scientific literature regarding the enhancement of clam stocks three general methodologies emerge: 1) enhancement of natural recruitment using wild spat; 2) transplantations from nearby natural populations; and 3) reseedling using hatchery-reared stock (Arnold 2002; Tettelbach et al. 2002). Option 3 involves developing a hatchery in which spat from wild or captive toheroa is developed and released when believed to be resilient enough survive in the environment. This option is the most expensive. However, toheroa have been successfully spawned in laboratory conditions (Smith 2003) proving toheroa are suitable candidates for this type of aquaculture-based enhancement methodology.

It appears toheroa have traditionally been transplanted within Murihiku using the above option two. The movement of surplus toheroa is relatively inexpensive (Futter & Moller 2009) and provides an excellent opportunity to increase the collaborative management partnership between kaitiaki and scientists. The trial and error nature of future translocation attempts will increase the knowledge held surrounding the ecology and behaviour of toheroa. Kaitiaki and scientists need to pool their knowledge to maximise translocation success in regard to site selection and

methodology. Translocations have been used successfully to reseed barren areas within the former range of *Taitokerau toheroa* (Akroyd 2004). Consultation with the *Taitokerau kaitiaki* would accelerate the development of successful translocation techniques for the *Murihiku toheroa*.

The majority of marine translocations are undertaken with the primary incentive of ensuring commercial fisheries (i.e. for monetary gain) and also to support community's growing populations and demands (Richards et al. 1994). However, given the obligations of *kaitiaki* to help ensure *kai moana* stocks are there for their *mokopuna* (grandchildren) and the limited distribution and *taonga* status of *toheroa*, sufficient motivation is provided for the active management of this resource to ensure its persistence for both cultural health and wellbeing and biodiversity conservation reasons. To restore *toheroa* populations in *Murihiku* to resemble historical numbers is desirable.

6.4 Monitoring

The robust population surveys of the *Murihiku toheroa* populations provide excellent baselines from which the success of future management regimes and restoration actions can be assessed. Continued monitoring is essential to assess the success of newly implemented management regimes and translocation efforts. The *Murihiku kaitiaki* expressed concern regarding the lack of adherence of the current monitoring methods (excavation surveys) to the *tikanga* of not using digging implements. Preliminary investigations into the use of the non-invasive traditional search method (i.e. identifying siphon tips/holes) yielded a poor index of the density estimates generated from the excavation surveys at each of the three beaches. Further investigation including a larger range of variables may improve the predictive power of siphon activity counts to excavated quadrat densities. If a coarse index of *toheroa* density was successfully developed at the most it could be used in conjunction with the excavation studies. Both juvenile recruitment and stock structure (not assessed with the siphon counting technique) are both valuable parameters when assessing the status of a population.

Although a poor indicator of *toheroa* density the observation of siphon activity (i.e. siphon tips/holes) can readily be applied to investigating the distribution of *toheroa* colonies. This traditionally based indicator will enable *kaitiaki* to assess the primary success of translocation efforts and boundaries of *toheroa* colonies in a simple, non-

invasive way. Another practical method of monitoring the toheroa resource is to formalise catch per unit effort data. A stipulation of each customary authorisation is that the applicant must inform the Tangata Tiaki about how many shellfish or fish they actually caught. A simple form could be designed, through which harvesters provide details regarding the search/harvest methods used, distribution of effort, search times and number of harvesters (e.g. Kitson 2004). Interviewees noted a large increase in the time taken to catch a feed of toheroa in their life time, and this corroborates the general decline seen in toheroa population size from scientific surveys (Beentjes & Gilbert 2006a,b).

6.5 Co-management and the relevance of mātauranga

In order to manage natural resources effectively there needs to be a comprehensive understanding of all available knowledge. In a co-management partnership between indigenous peoples and scientists, the two disciplines can successfully identify the gaps in this knowledge and devise the best approaches to fill such gaps. Combining TEK systems with those of modern science creates an opportunity to resolve past management conflicts and ensure the most effect resource management regimes are developed (Moller 1996; Moller et al. 2004; Newman & Moller 2005).

With both TEK and science knowledge systems available to kaitiaki, they will be more informed and have a strengthened ability to manage natural resources. More information will help in responding to changes in natural resources statuses and to revise harvest practices and/or management strategies if they see fit (Moller & Kitson 2008). The inclusion of the toheroa under the Customary Fisheries Regulations has allowed the kaitiaki to exercise a higher degree of kaitiakitanga over their taonga species. The high degree of support for traditional practices being adhered in relation to toheroa harvesting in the interview discussions indicates the relevance of kaitiakitanga in current day toheroa management.

Recurring overarching themes that emerged unprompted in the interview discussions included respect for the environment and other people and the reciprocity between people and the taonga, in this case toheroa. These broad themes are reflected in several other customary harvests by Māori in New Zealand (Kitson & Moller 2008; Lyver & Moller in press; Moller & Lyver in press), and the views were clearly shared by many Pākehā participants in this study. Worldwide, institutions that direct traditional management have developed rules of use that are embedded within their

customs and religious beliefs (Colding & Folke 2001). These practices are generally social restrictions but have great promise to ensure sustainable resource management (Berkes 2008; Kitson & Moller 2008). There is the potential for the traditional management practices of indigenous peoples to be misinterpreted or the principles missed completely by modern scientists. The development of comprehensive dialogues are needed between the two groups to create an understanding and respect for each other's knowledge system (Huntington 2000).

The benefits of interviewing kaitiaki (or the equivalent) and local experts goes well beyond the valuable, specific information received. Participation in the research builds ownership and control by the kaitiaki along with additional benefits of re-engaging with their traditional philosophies and practices. This re-engagement allows the people to reconnect with traditional resources and revitalise their culture (e.g. Moller et al. 2009b; Schweikert & Moller in press). Participation at all levels builds and locks-in environmentalism (Agrawal 2005) amongst the kaitiaki and other stakeholders that impact upon or wish to support natural resources such as toheroa.

6.6 Transmission of mātauranga Māori

Many indigenous people transmit their TEK and customary practices through participatory learning and oral transfer (e.g. Ulluwishewa et al. 2008). Thus there is a need to maintain a connection with wildfoods to ensure that the knowledge and traditions are upheld and understood. Kitson & Moller (2008) emphasised the importance of developing avenues to ensure TEK is transferred to the younger generations. In recent years, a trend towards the documentation of TEK to prevent further knowledge erosion has developed. The need for such methodologies has emerged due to the breakdown of transmission of knowledge and traditional practices. This breakdown is largely the result of indigenous people assimilating into western society (Turner *et al.* 2000). Many elders hold specialised knowledge and much of their knowledge is being lost with them. This is proven true in this present study by the loss of important details regarding the ingredients of the supplement feed developed by one local kaitiaki and the use of pōha to transplant wild toheroa spat. Lyver et al. (2008) reported that the failure to adhere to the tikanga and practices surrounding the kereru (New Zealand wood pigeon, *Hemiphaga novaseelandiae*) is responsible for the pigeons current conservation status. Secrecy of knowledge (i.e. not sharing indigenous knowledge with outsiders) is another avenue in which value information can be lost. Overcoming indigenous peoples'

mistrust in collaborative management is essential to developing the most informed and all round beneficial management regimes for natural resources.

6.7 Conclusions

TEK is generally finely tuned to local areas and consultation with this knowledge source is invaluable (Moller & Lyver 2008). When the mātauranga and modern science surrounding the Murihiku toheroa were aligned, common goals and parallel assessments in the trends and status of the toheroa stocks were identified. This present study clearly indicates the importance of meaningful discussions with the local people to improve the understanding of: 1) aspects of toheroa ecology; 2) the primary threats/concerns relating to the sustainability of toheroa stocks; 3) potential enhancement/restoration techniques and 4) how to conduct science in a culturally sensitive way. The combination of mātauranga and modern science helps reduce the uncertainty of knowledge regarding toheroa. Consultation with kaitiaki can dictate research priorities, as was done in this present study, ensuring efforts are spent effectively on research that will aid in the sustainable management of precious resources such as toheroa.

The Murihiku toheroa populations are smaller relative to historic levels. Tangata Tiaki have the responsibility and obligation to allow their people access to their kai and the opportunity to maintain the connection with the surrounding tikanga and mātauranga but also to ensure the resource is managed in a sustainable way. The present study identifies the concerns and gaps in the knowledge regarding toheroa ecology. Future research investigating aspects of sustainable harvesting and threat management will help ensure the resilience of the Murihiku toheroa meta-population.

Understanding (and mitigating if practical) the reasons causing variable recruitment success in conjunction with determining the most sustainable harvest size will help enhance toheroa breeding stocks. Although the traditional search technique did not transfer well to a monitoring tool it provides a non-invasive method for monitoring presence/absence and determining the boundaries of colonies. Furthermore the importance of including the scientific surveys is outlined in accurately accessing population parameters. Beach traffic has proven to have detrimental effects on the survival of juvenile toheroa. Upon assessing the degree and spatial occurrence of beach traffic on each of the three beaches and locating important juvenile beds,

regimes to direct traffic away from these sensitive areas could be developed to help maintain successful recruitment to maturity. Relocation of the BMC race track in combination with restricted the number of vehicles entering on to the beach would largely reduce this event's impact on the Oreti Beach toheroa colony. Translocation of toheroa to appropriate receiver sites while large enough populations exist to support this technique may hold the key to increasing the resilience of the Murihiku toheroa meta-population.

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Appendix 1. Results from backward stepwise exploration of the linear regression model investigating the predictive power of siphon activity density. Steps included a) the investigation of which density data formation was best; b) which beach or combination of beaches had the best model. Significance of predictor variables are given as p-values. ANOVA results so predictive ability of whole model. QD = density from excavation quadrats and SC = density from siphon activity counts.

	All Beaches	Oreti and Orepuki	Oreti	Orepuki	Bluecliffs
<i>QD vs log₁₀SC</i>					
<i>n</i>	183	158	71	87	25
Constant*	0.598	0.520	0.755	0.000	0.427
Beach*	0.002	0.001	-	-	-
log₁₀SC*	0.096	0.053	0.036	0.052	0.566
Air temp*	0.124	0.007	0.320	0.000	0.974
Wind speed*	0.884	0.322	0.652	0.005	0.261
Cloud cover*	0.191	0.064	0.687	0.001	0.067
Tide direction*	0.113	0.267	0.735	0.498	0.447
R²(adj)	9.3%	11.6%	10.7%	19.1%	3.9%
ANOVA^μ	0.001	0.000	0.030	0.000	0.350
N° of unusual cases	10	6	3	5	2
<i>Log₁₀ QD vs log₁₀ SC</i>					
<i>n</i>	124	116	58	58	8
Constant*	0.645	0.873	0.806	0.013	0.983
Beach*	0.003	0.002	-	-	-
log₁₀SC*	0.597	0.321	0.222	0.170	0.860
Air temp*	0.156	0.043	0.726	0.004	0.945
Wind speed*	0.301	0.104	0.978	0.006	0.958
Cloud cover*	0.907	0.712	0.833	0.293	0.772
Tide direction*	0.452	0.775	0.647	0.327	∓
R²(adj)	6.6%	8.4%	0.1%	12.0%	0.0%
ANOVA^μ	0.030	0.016	0.417	0.039	0.100
N° of unusual cases	11	5	8	2	2

∓ Minitab eliminated tide from this model as it was highly correlated with another predictor variable.

* Regression coefficient

^μp-value